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ELECTRICAL EFFECTS ASSOCIATED WITH A CHANGE OF STATE OF WATER

By J. E. Dinger and Ross Gunn

Abstract—A method for measuring the change in contact-potential of a water-air interface as the water freezes or melts is described. These measurements indicate that a change of the order of ten volts rapidly occurs at the time of freezing of the surface of the water. After freezing this contact-potential diminishes, the rate depending upon the temperature of the ice, until the potential is approximately that which existed before freezing. The melting of the ice produces no appreciable change in the contact-potential. A method for approximately measuring the charge acquired by air passing over a given volume of freezing or melting water is described. A method of measuring the charge acquired by a given volume of water upon melting is described and the results are consistent with other measurements which determine the charge acquired by the air in contact with the melting water. Distilled water that has been frozen in an atmosphere of air, upon melting acquires a positive charge of approximately 1.25 esu for each cc of melted water, and simultaneously the surrounding air acquires a negative charge of 1.25 esu for each cc of the melted water. The presence of impurities reduces and with sufficient concentration neutralizes this charging-effect accompanying the melting process. The presence of dissolved gases is essential for the observed charging-effect to occur. This fact indicates that the charging-effect is related to earlier experiments on the cataphoresis of gas bubbles as described in the literature. No important charge-production accompanies the freezing of even pure water in the absence of dissolved gases.

Introduction

A number of theories and methods have been advanced to account for the charges appearing on all kinds of atmospheric precipitation [see 1 to 8 of "References" at end of paper], and to account for the separation of electricity in clouds. These theories go far in explaining the processes of separation of charges, but none of them offers a complete explanation of all aspects of the observed facts; therefore, it seems probable that all mechanisms for charging atmospheric precipitation have not as yet been considered. It is known that atmospheric precipitation may experience the process of alternate freezing and melting a number of times while it is in a cloud or falling earthward. Therefore, the question arises: Is a change in state of water accompanied by a net change in the quantity of electricity appearing on

the precipitation? It is the purpose of this investigation to make laboratory observations which will determine whether a separation of electricity does accompany a change in state of water and, if so, what are the processes involved.

The experiments discussed in this paper are divided into three parts, namely: (1) A measurement of the change in contact-potential accompanying the freezing or melting of water; (2) a measurement of the charge acquired by the air passing over water which is undergoing a change in state; and (3) a measurement of the charge acquired by water during the melting process. These three investigations will be considered separately in the above order.

Measurement of the change in contact-potential accompanying the freezing or melting of water

When two substances of different composition are placed in contact, in general it can be said that a difference in potential will exist between the two substances. This difference in potential is commonly called contact-potential. This contact-potential is a result of the preferred orientation of the surface layer of molecules in each substance and, because of the dipole nature of the molecules, there is present a double layer of electricity. The magnitude and sign of this double layer varies from one substance to another and for a given substance its value is dependent upon the condition of the surface, that is, whether the surface is clean, has a film of oxide present, etc. As water goes from the liquid to solid state, it is reasonable to expect a change in the surface double layer of electricity which will be indicated by a change in contact-potential.

The method used for measuring the contact-potential is the classical one shown in Figure 1. The platinum plate P is electrically insulated by the polystyrene rod I, but it is electrically connected to the central system of the electrometer EL. The ground of the electrometer is connected to the copper rod C through the potential-divider AB, so that a potential-difference (determined by the voltage E and the position of a) can be inserted between ground and C. The platinum pan Q makes electrical and thermal contact with C by means of the mercury M. Consider now the potential φ_1 of a point just outside the surface of P. Consider also the potential φ_2 of another point just outside the surface of the water W. In general, when S_1 is closed and the sliding contact a is at A, the potentials of φ_1 and φ_2 will not be equal, so there exists an electric field between P and W. These potentials are different because of the difference in the double layers existing at the platinum-to-air and water-to-air boundaries. It can be shown that the nature of the electrical conductors connecting P and W do not influence the values of the potentials φ_1 and φ_2 if none of the conductors are electrolytes. If S_1 is opened, thus isolating the central system of the electrometer, and,

if the plate P is moved so that the spacing of P and W is altered, a deflection of the electrometer will result. This is true because P and W can be considered as plates of a condenser charged to a potential-difference of $(\varphi_2 - \varphi_1)$. If the spacing of P and W is changed, the capacity of the condenser must change, and since the charge on the condenser is fixed on the central system of the electrometer, it follows that the potential across the condenser must change, resulting in a deflection of the electrometer. A zero-deflection of the electrometer will result when the P-to-W spacing is changed only if, at the moment S_1 is opened, $\varphi_1 = \varphi_2$. φ_1 can be made to equal φ_2 by inserting a potential-difference V of the proper value and polarity between the electrometer and C. A measure of this potential-difference, as indicated by the voltmeter V, gives the value of $(\varphi_2 - \varphi_1)$, before the potential-difference V was inserted. The experiment thus involves using the electrometer as a null-indicating instrument to enable one to determine the potential-difference V required to equal $(\varphi_2 - \varphi_1)$. The water W in the platinum pan Q can be frozen by immersing the copper rod C in a bath BA consisting of a mixture of solid CO_2 and alcohol. Likewise the ice can be melted by changing BA to hot water. Platinum was chosen as the metal for plate P because platinum presents a relatively stable surface and is easy to clean. The platinum-to-air potential-difference was thus assumed to be constant and any change occurring in $(\varphi_2 - \varphi_1)$ was attributed to changes occurring in the surface of the ice or water.

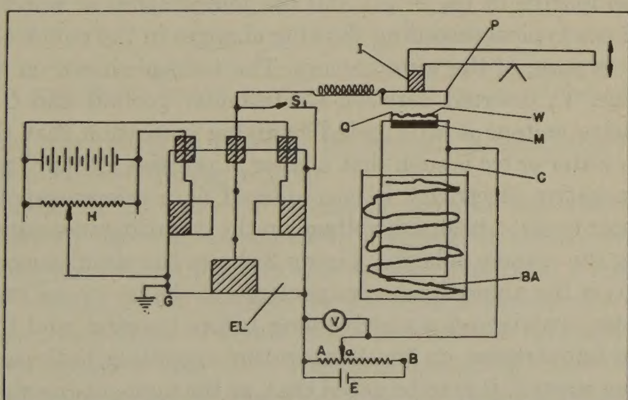


FIG. 1—SKETCH OF APPARATUS SHOWING METHOD FOR MEASURING CHANGE OF SURFACE CONTACT-POTENTIAL ACCOMPANYING CHANGE OF STATE OF WATER

In the taking of data, the voltmeter V is a recording voltmeter with provision for rapidly changing to any one of three ranges. One junction of a copper-constantan thermocouple is immersed in the mercury M, the other junction being in an ice bath. The emf of this thermocouple is measured with a potentiometer. The sliding contact of this potentiometer is mechan-

ically coupled to a voltage-dividing circuit such that a voltage, proportional to the position of the potentiometer sliding-contact, is recorded on a recording voltmeter. In this way a record of the changing temperature is obtained by manually maintaining a balance of the potentiometer. The temperature of M will not always be the true temperature of the water. However, good thermal contact exists between the mercury and water so that the temperature of the mercury may be assumed to be that of the water except when the temperature is changing rapidly.

The taking of data requires two observers and the procedure is briefly as follows: Switch S_1 is opened and plate P is moved up and down while the direction and magnitude of the deflection of the electrometer are noted. S_1 is closed and an adjustment of the position of contact a is made. A little experience enables the observer to estimate the amount of adjustment required. S_1 is again opened while plate P is moved and the electrometer-deflection is observed to determine whether the proper adjustment of contact a has been made so that a zero-deflection of the electrometer results. This procedure is continued, always attempting to maintain the settings of the contact a such that the electrometer-deflection is zero when the P-to-W spacing is being changed. In this manner, any change in contact-potential of the water can be followed and recorded as the water freezes or melts. The second observer simultaneously follows the change in thermocouple voltage by means of the potentiometer. The two recorders thus give simultaneous records of $(\varphi_2 - \varphi_1)$ and the temperature of water or ice.

Figure 2 is a typical recording showing changes in the contact-potential as a change in state of the water occurs. The voltage shown on the record is the voltage, V, inserted between electrometer ground and C (Fig. 1). Thus a positive voltage is interpreted as giving indication that the double layer on the water or ice is such that a layer of positive electricity and then a layer of negative electricity is encountered as a reference-point passes from the water to air; a negative voltage on the recording indicates a double layer having the reverse polarity. Figure 2 shows the simultaneous recording which gives the approximate temperature of the ice or water. In every case the water experienced a supercooling before freezing, and the sudden small rise in temperature on the temperature recording indicates the moment freezing started. It is to be noted that, at the moment freezing started, no change in contact-potential was indicated. Freezing always started at the bottom of pan and proceeded upward, and not until the surface layer started freezing was there any evidence of a change in contact-potential.

Because the method of following changes in contact-potential was a "seek-and-find" method, the dotted line has been added to give a smooth curve which more nearly indicates the correct voltage at all times. The points at which the dotted line touches the steps of the solid line are points at which the electrometer gave a null-indication.

Figure 2 shows a typical run in which the change of temperature was such that cracking of the ice during freezing was avoided. Before freezing starts, a positive potential of approximately 0.25 volt is indicated. At the moment surface freezing started, the potential reversed polarity and quickly reached a maximum negative voltage of 7.5 volts, after which the voltage returned in an approximately exponential manner to about the value existing prior to freezing. The return portion of the cycle we shall refer to as the decay-period. During this particular decay-period, the temperature was such that the water was in a solid state. After the voltage had returned to a value approximately the same as that existing before freezing started, the

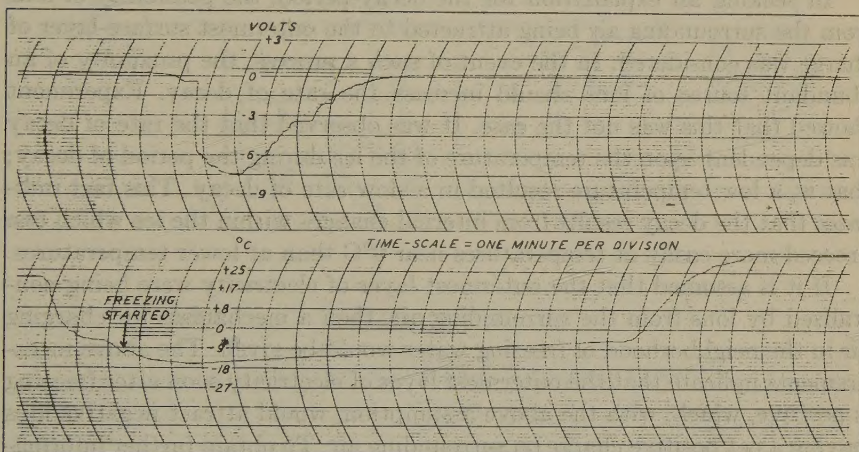


FIG. 2—SIMULTANEOUS RECORDS OF CONTACT-POTENTIAL AND TEMPERATURE OF ICE

temperature was raised so that the ice melted. No important change in potential is evidenced during melting.

In a number of instances the change in potential followed a somewhat different pattern than the one shown in Figure 2. In these cases the usual positive potential existed prior to the starting of surface freezing. At the moment of freezing of the surface, the potential experienced a sharp positive increase to a voltage of about four volts followed by a sudden change to a negative voltage of nine volts. The decay-period then followed the usual pattern. The duration of the positive swing was about 30 seconds.

An attempt was always made to avoid cracking of the ice. Cracking is always accompanied by the appearance of large potentials, sometimes as great as 50 volts. These large potentials are undoubtedly caused by electrostatic phenomena other than a change in the surface contact-potential.

We can summarize the results of a large number of runs, of which Figure 2 is typical, briefly as follows: The potential V required to give a null-deflection when the water is in the liquid state is $+ 0.25$. As the surface of the water starts freezing, the potential quickly assumes a value of the order of

– 6 to – 10 volts, if no cracking occurs. In some cases the change to the negative potential may be preceded by a rapid excursion of the potential to a value of + 4 to + 6 volts. In either case, after the maximum negative potential has been reached, a decay-period follows during which the voltage returns to approximately + 0.25 regardless of the temperature of the ice. Freezing accompanied by cracking may produce potentials as great as – 50 volts. In all these runs it was necessary to use distilled water. The addition of small amounts of an impurity, such as alcohol or the use of tap-water, resulted in runs which failed to give an indication of any change in the contact-potential accompanying a change in state.

In seeking an explanation for the decay-period, the possibility of ions from the surrounding air being attracted to the outermost surface-layer of charge was considered. In the event of such a process, the proximity of an abundant source of ions should increase the rate of decay. Experiment showed that this was not the case. It was observed that the rate of decay was dependent upon the temperature of the ice during the period of decay; that is, a low temperature resulted in a slow rate of decay. This fact indicates that the decay results from internal changes within the ice which can proceed more easily at temperatures near 0°C than at lower temperatures.

If it is assumed that the outermost layer of electricity were being neutralized by ions from the surrounding air, then a mechanism for charging air in the neighborhood of freezing water would be given. The above measurements indicate that the outermost layer of electricity soon after freezing is positive, which, with the above assumption, would attract negative ions leaving a net positive charge on surrounding air. To obtain further information on this point, the following experiments were undertaken.

Measurement of charge acquired by air passing over water which is undergoing a change of state

Figure 3 illustrates the apparatus and method used for measuring charge acquired by the air as it is drawn across the freezing or melting water *W* by the fan *F*. The water is made to freeze or melt by circulating alcohol *AL*, by means of the pump *P*, through the closed system consisting of the jacketed tube *J*, the pump *P*, and the coil *Co*. By immersing the coil *Co* in a bath, *BA*, of solid CO_2 and alcohol or hot water, the water *W* can be frozen or melted as desired. The thermometer *TH*, indicates the temperature of the circulating alcohol. The tube containing the water *W* consists of a 1½-inch copper tube which is nickel plated on the inside. Three lengths of this jacketed tube were used, namely, 4, 8, and 16 inches.

The ends of the tube are partially closed so that the water *W* has a depth of about one-third the diameter of the tube. Tube *R* is highly insulated from the rest of the system by the polystyrene rings *I*. The tube *R* is filled with copper turnings *T*, and thus serves as an ion-catcher for ions in

the air-stream passing through R. R is electrically connected to the central system of the electrometer EL. The electrometer and all parts of the apparatus which make connections to the electrometer are enclosed in the grounded metal box M.

The procedure for obtaining data is as follows: A known amount of water W is placed in J. The fan F is started. Switch S_2 (which is normally

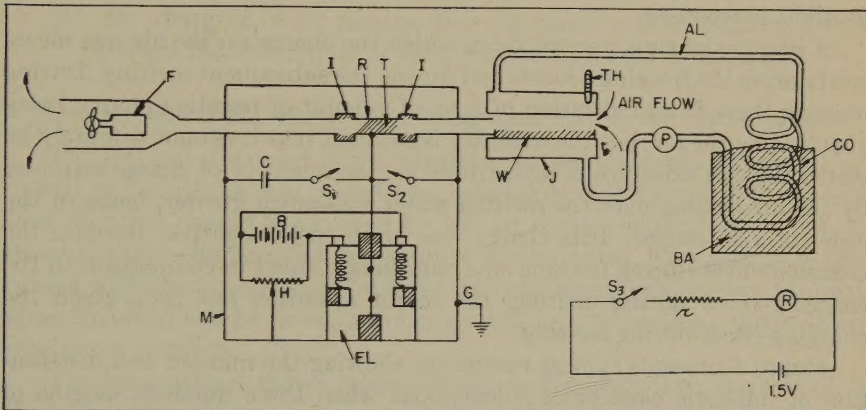


FIG. 3—SKETCH OF APPARATUS FOR MEASURING ELECTRICAL CHARGE ACQUIRED BY AIR WHILE PASSING OVER WATER THAT IS UNDERGOING CHANGE OF STATE

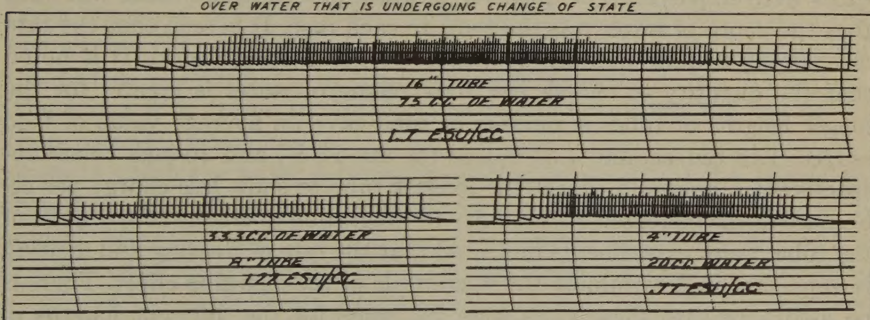


FIG. 4—PHOTOGRAPHS OF RECORDS SHOWING TIME-DISTRIBUTION AND QUANTITY OF CHARGE ACQUIRED BY AIR PASSING OVER MELTING ICE

closed) is opened. The alcohol AL is circulated, by means of pump P, through the closed system with the coil Co immersed in a mixture of solid CO_2 and alcohol. The deflection of the electrometer EL is noted as the water W freezes. After the water W is completely frozen, the bath BA is changed to hot water so that the water is subsequently melted. The electrometer-deflection is noted during the process of melting. Knowing the deflection and sensitivity of the electrometer, as well as the electrical capacity of the central system of the electrometer, the total charge collected from the air-stream by the ion-catcher R is readily calculated. The use of a known capacity C provides a method for measuring the capacity of the central

system. In most instances the deflection of the electrometer is greater than a full-scale deflection. Therefore, when a full-scale deflection is attained, the switch S_2 is momentarily closed, thus returning the electrometer to zero. The switch S_3 in the circuit shown in the lower part of Figure 3 is ganged with switch S_2, so that the momentary closing of S_3 gives a momentary deflection of the recorder R. Thus the total number of full-scale deflections of the electrometer as well as the time-distribution of the deflections is recorded.

A number of runs were made in which the charge on the air was measured during the freezing process and during the subsequent melting. During freezing there is an indication of a small amount of negative charge being acquired by the air, but the quantity is so small that it cannot definitely be stated that its existence is real. However, the quantity of charge acquired by the air passing over the melting water was much greater, being of the order of 1.25 esu/cc. This charge was in all cases negative. Because the charging-effect during freezing was vanishingly small in comparison to the charging-effect during melting, the major attention has been given the charging-effect during melting.

Figure 4 presents typical recordings showing the number and distribution of full-scale electrometer-deflections when three different lengths of tubes were employed. The quantity of water placed in the tubes was such that the depth of water was the same in each case. It is seen that the rate of charging is quite uniform over most of the melting period. It is noted that the quantity of charge per unit-volume of water is greater for the longer lengths of tube. A number of runs gave an average value of 0.45 esu/cc, 1.13 esu/cc, and 1.51 esu/cc for the 4-, 8-, and 16-inch tubes, respectively. One would expect the longest tube to show less charge per cc, because of the increased opportunity for migration of charge to the walls of the tube. Later experiments indicated that the rate of freezing and melting is important in determining the magnitude of the charging-effect. There is no assurance that these rates were the same for the different lengths of tubes which may therefore account for the different magnitudes of electrification.

The use of tap-water or water to which a slight amount of alcohol or sulfuric acid had been added, failed to give any detectable electrification. It was necessary therefore to use distilled water in order to get a pronounced electrification.

A number of observations were made in which the ice was kept completely submerged throughout the entire melting-process. We were surprised to observe that the charging-effect was but very slightly reduced, although the ice was completely covered with water during the entire melting-process. The fact that the charging-effect continues even though the ice is completely submerged indicates that the effect is concerned with the

volume of melting ice, and it is not a phenomenon concerned with the surface of ice exposed to the air or water.

The change in contact-potential discussed in the first portion of this paper does not appear to be a factor in the charging-effect accompanying the melting of ice as evidenced by the following observations:

(1) The changes in contact-potential accompany freezing, whereas the charging-effect accompanies melting; and

(2) The charging of air passing over the water and ice continues even though the melting ice is completely submerged in the water.

Measurement of the charge acquired by water during the melting process

The method discussed in the previous section measures the charge acquired by the air that has passed over freezing or melting water. It was seen that negative charge is acquired by the air during melting; therefore, an equal positive charge must be acquired by the water. This section is concerned with the measurement of this positive charge; and because the variables involved can be brought under control by this method, quantitative results are possible.

The apparatus is shown schematically in Figure 5. The alcohol AL in the closed circulating system is circulated through the coil CL_1, this coil being immersed in the bath BA, which consists of a solution of solid CO_2 and alcohol. The alcohol is subsequently circulated through either the coil CL_2 or CL_3 as determined by the positions of the cocks K_1, K_2, K_3, and K_4. The water W is frozen in the platinum pan Q by placing the pan on the copper slug C_1, which has been cooled to a desired temperature. The atmosphere in which the water is frozen is selected by admitting the desired gas into the bell jar J. When an atmosphere of air is desired the bell jar is removed. After the water is frozen under the desired conditions, the pan Q is transferred to the copper slug C_2. C_2 is electrically connected to the central system of the electrometer EL, the central system being highly insulated from ground by the polystyrene block I. The fan F circulates the air within the enclosure formed by the cylindrical coil CL_3. The temperature of the air within the enclosure is controlled by circulating the alcohol AL through the coil CL_3, and thus the rate of melting of the water is determined. As the water melts, the accumulation of charge on the water produces a deflection of the electrometer. Knowing the total deflection, the electrometer-sensitivity, and the electrical capacity of the central system of the electrometer, the total charge is readily computed.

The factors which may be expected to have an effect upon the electrification of melting water include (1) rate of freezing, (2) rate of melting, and (3) purity of water. In order to determine the importance of each factor, it is necessary to make a series of observations in which only one of these

factors is permitted to vary in a known manner throughout the series of observations.

(1) *Effect of initial rate of freezing*—A series of observations was made in which the rate of freezing was varied from one observation to the next. The freezing-rate is determined by the temperature at which the copper slug C_1 (Fig. 5) is maintained during the freezing; therefore, the tempera-

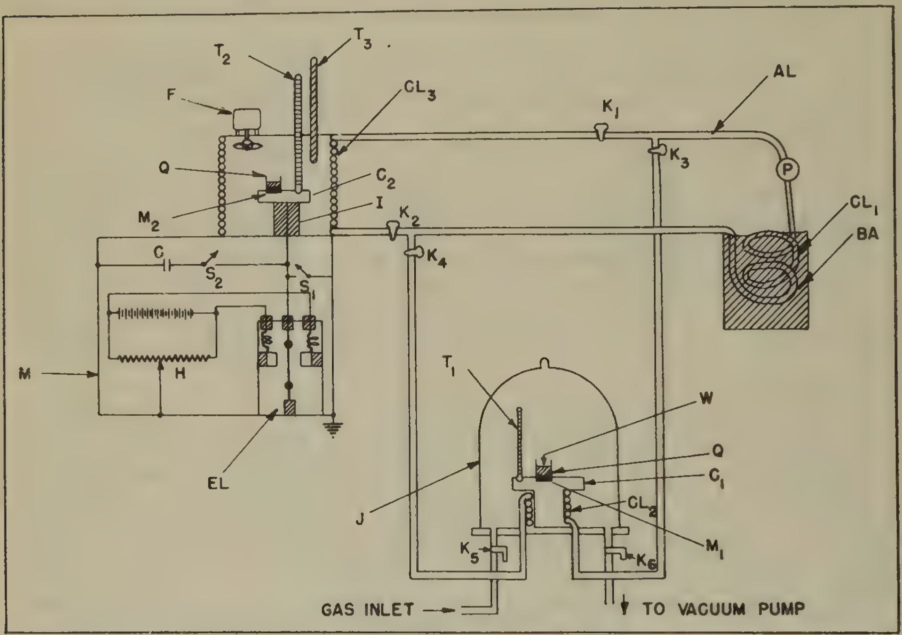


FIG. 5—SKETCH OF APPARATUS FOR MEASURING ELECTRICAL CHARGE ACQUIRED BY WATER WHEN GOING FROM SOLID TO LIQUID STATE

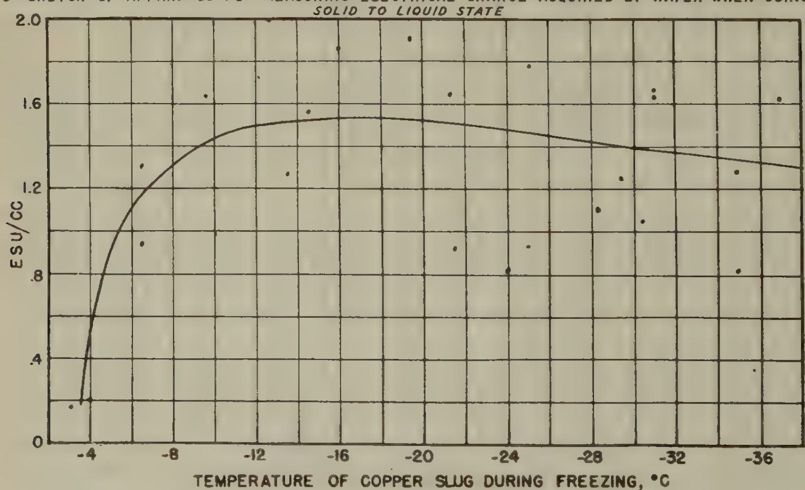


FIG. 6—EFFECT OF INITIAL RATE OF FREEZING

ture of C_1 is a measure of the rate at which the water freezes. Each specimen of water for each observation was taken from the same flask of distilled water, thus assuring that all observations were made with water of the same degree of purity. In making an observation, the platinum pan Q is placed on the copper slug C_1 and permitted to reach thermal equilibrium. Two cc of water are placed in the pan by means of a graduated pipette. The water does not wet the cold platinum surface; therefore, the water forms a globule, thus permitting the ice to expand during freezing without cracking the ice. After the water is frozen, Q is transferred to C_2 and the ice is melted while the fan F is running. The rate of melting is made equal for all observations by making the temperatures as indicated by T_2 and T_3 equal to a given value at the time Q is transferred to C_2.

The curve of Figure 6 shows that the charge per cc of water acquired by the melting water varies with the rate of freezing, the rate of freezing being indicated on the graph as the temperature at which the copper slug C_1 was maintained during freezing.

(2) *Effect of rate of melting*—A series of observations was made in which the effect of varying the rate of melting was determined. The rate of melting for a given observation is determined by the value of the initial temperature (indicated by T_2, Fig. 5) of the copper slug C_2, as well as the air-temperature (indicated by T_3) within the enclosure. The rate of freezing was held constant for all observations by maintaining the temperature of the copper slug C_1 constant throughout the freezing process. All specimens of water were taken from the same flask of distilled water. The procedure for each observation was the same as that described in (1) above.

Figure 7 is a graph showing the results of 30 observations. The charge per cc of water acquired by the water is plotted against the time required for melting.

(3) *Effect of dissolved impurities*—The purity of the water can be altered by dissolving a liquid, solid, or gas in the water. In case the resulting solution becomes acidic or alkaline, the value of the pH of the solution is a measure of the amount of a particular solute present. The conductivity of the solution is changed if the presence of the solute changes the number of free ions.

(*a*) *Effect of the pH of the solution*—Specimens of water were made having different values of pH. Various concentrations of NaOH were used to give specimens having a pH ranging from 7 to 12 whereas HCl was used in varying concentration to give specimens having values of pH ranging from 1 to 7. The value of the pH of each specimen was measured by means of a Beckman pH-meter. Two cc of water of a given specimen were frozen in pan Q by placing the pan on copper slug C_1, and maintaining the copper at a temperature near $-25°C$. After freezing, Q was transferred to C_2 and the electrification accompanying the melting was measured. The rate of

melting was made the same for all observations by having the initial temperature of C_2 at a value near 12°C.

Figure 8 shows the charging-effect accompanying the melting as a function of the pH of the water. It is seen that values of pH less than 2.5 and greater than 10 reduce the electrification to zero. The concentration of the specimen as well as the pH is indicated on the abscissa.

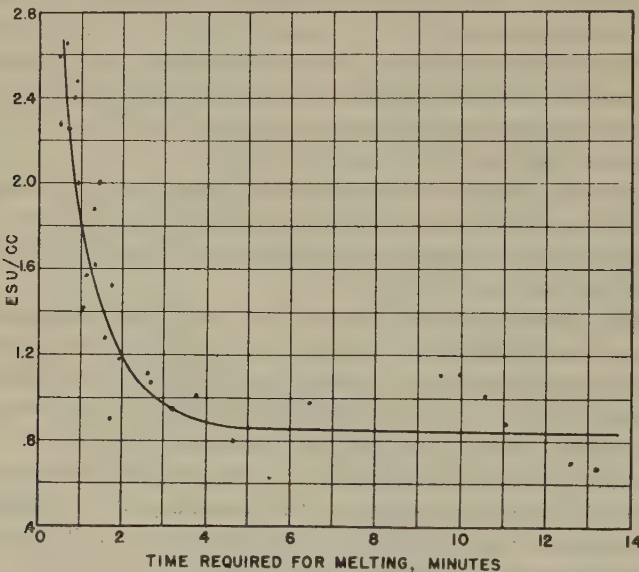


FIG. 7—EFFECT OF RATE OF MELTING

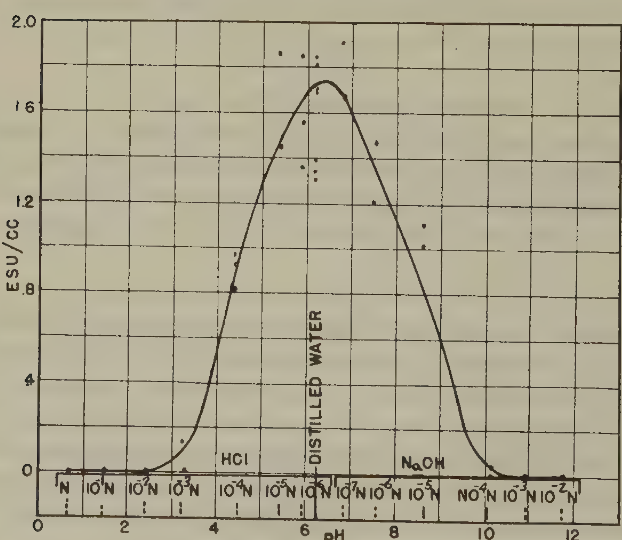
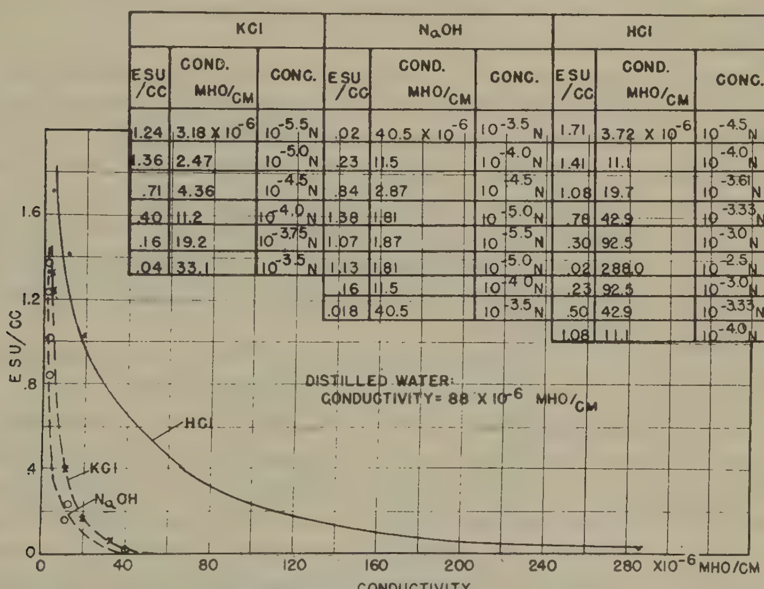


FIG. 8—EFFECT OF THE pH OF SOLUTION

(*b*) *Effect of conductivity of solution*—Specimens of water having different conductivities were made. Three series of specimens were made by using varying concentration of NaOH (a base), KCl (a salt), and HCl (an acid). The conductivity of each specimen was determined by the use of a conductivity-cell in one arm of a bridge employing 1000 cps.

Figure 9 shows the charge acquired during melting per cc of solution as a function of the conductivity. It can be seen that the use of solutions of KCl and NaOH reduced the charging-effect to zero at a much lower value of conductivity than is the case when the conductivity is determined by the concentration of HCl.



KCl			NaOH			HCl		
ESU/CC	COND. MHO/CM	CONC.	ESU/CC	COND. MHO/CM	CONC.	ESU/CC	COND. MHO/CM	CONC.
1.24	3.18×10^{-6}	$10^{-5.5}$ N	.02	40.5×10^{-6}	$10^{-3.5}$ N	1.71	3.72×10^{-6}	$10^{-4.5}$ N
1.36	2.47	$10^{-5.0}$ N	.23	11.5	$10^{-4.0}$ N	1.41	11.1	$10^{-4.0}$ N
.71	4.36	$10^{-4.5}$ N	.84	2.87	$10^{-4.5}$ N	1.08	19.7	$10^{-3.61}$ N
.40	11.2	$10^{-4.0}$ N	1.38	1.81	$10^{-5.0}$ N	.76	42.9	$10^{-3.33}$ N
.16	19.2	$10^{-3.75}$ N	1.07	1.87	$10^{-5.5}$ N	.30	92.5	$10^{-3.0}$ N
.04	33.1	$10^{-3.5}$ N	1.13	1.81	$10^{-5.0}$ N	.02	288.0	$10^{-2.5}$ N
			.16	11.5	$10^{-4.0}$ N	.23	92.5	$10^{-3.0}$ N
			.018	40.5	$10^{-3.5}$ N	.50	42.9	$10^{-3.33}$ N
						1.08	11.1	$10^{-4.0}$ N

FIG. 9—EFFECT OF CONDUCTIVITY OF SOLUTION

(*c*) *Effect of dissolved gases*—During the freezing of the water in all of the preceding observations, it was noticed that dissolved gases were trapped in the form of small bubbles in the ice. Upon melting, these small bubbles were released from the ice and arose to the surface of the water and escaped. The question, therefore, naturally arose as to whether these entrapped bubbles played a role in the electrification accompanying the melting.

By use of the apparatus sketched in Figure 5, the kind of dissolved gas present in the water before freezing was controlled. Approximately ten cc of distilled water were placed in the platinum container Q on the copper slug C_1. The bell jar J was placed over the water and the interior of the jar evacuated by means of a vacuum-pump. After obtaining a vacuum, the pump P circulated the alcohol through coils CL_1 (immersed in bath of CO_2 and alco-

hol) and CL_2, thereby causing the water in Q to freeze rapidly, thus driving the dissolved gases out of solution and entrapping the bubbles in the ice. After the water was completely frozen, the coil CL_1 was placed in a bath of hot water which caused the ice in Q to melt rapidly and release the bubbles of air into the vacuum above. This freezing-and-melting cycle was repeated in the vacuum two or more times. After removing all dissolved gas in this manner, K_6 was closed and K_5 opened to admit the desired gas into the bell jar at atmospheric pressure. The water was again frozen in the atmosphere of this gas by circulating the alcohol through the closed system with coil CL_1 immersed in the bath of solid CO_2 and alcohol. After freezing, Q was transferred to C_2 and the electrification during melting was measured in the manner previously described.

Oxygen, nitrogen, carbon dioxide, and hydrogen, in addition to air, were investigated in the above manner. Oxygen and hydrogen gas were obtained by electrolysis. The oxygen was passed through tubes containing copper oxide and soda lime to remove any hydrogen and carbon dioxide that may have been present. The hydrogen was purified by passing the gas over copper turnings heated to 450°C and also soda lime to remove traces of oxygen and carbon dioxide. Commercial nitrogen was used and purified in the manner used for hydrogen. Carbon dioxide was obtained by the sublimation of solid carbon dioxide.

The diameters of a representative number of the tiny entrapped gas-bubbles were measured by means of a traveling microscope.

Table 1 presents in condensed form the average of data obtained for a number of observations using the various gases. In this Table Column (3) gives the volume of a dissolved gas in a cc of water at 0°C and at the pressure in the bubble as corrected for surface-tension effects. Assuming this volume of gas to be dissolved in the water, the number of bubbles per cc of water is calculated as given in Column (5). The measured charge acquired per cc of water is given in Column (6), from which the charge per bubble is given in Columns (7) and (8).

Table 1—*Summary of data showing effect of dissolved gases*

Gas dissolved in water before freezing (1)	Radius, r, gas-bubble entrapped in ice (2)	Volume[a], V_G, dissolved gas per cc (3)	Volume, bubble, $V_B = (4\pi r^3/3)$ (4)	No. gas-bubbles per cc ice, $N = (V_G/V_B)$ (5)	Charge, Q, acquired one cc ice on melting (6)	Charge on each bubble, $Q_B = (Q/N)$ (7)	Charge on each bubble $Q'_B = Q_B \div 4.8 \times 10^{-10}$ (8)
	cm	*cc*	*cc*		*esu*	*esu*	*elem. units*
Oxygen	63.5×10^{-5}	39.2×10^{-3}	1.07×10^{-9}	36.8×10^{6}	0.64	1.75×10^{-8}	36.7
Nitrogen	175×10^{-5}	21.4×10^{-3}	2.25×10^{-8}	9.5×10^{5}	1.21	1.27×10^{-6}	2680
Air	134×10^{-5}	26.4×10^{-3}	1.01×10^{-8}	26×10^{5}	1.19	4.57×10^{-7}	950
Carbon dioxide	No measurements	...	...	No measurements	None	...	...
Vacuum	...	...	...	None	None	...	...
Hydrogen	No bubbles measured	...	...	...	0.043	...	...

[a]Under conditions of pressure and temperature in bubble.

It has been pointed out that the electrification accompanying the melting process was only slightly changed by submerging the ice completely under water. Referring to Figure 4, we see that the charging-effect proceeded quite uniformly throughout the melting process. It appears, therefore, that the rate of electrification from ice frozen under a given set of conditions depends largely on the rate of decrease of the volume of the ice and not on the surface of the ice that is in contact with water or air.

The question arises concerning the mechanism which makes possible the escape of negative charge into the air from ice which is completely submerged in water. Table 1 shows that ice which is completely devoid of entrapped air-bubbles shows little or no electrification during melting. Water which is free of dissolved gases and subsequently frozen in an atmosphere of hydrogen, produces ice which is practically free of gas-bubbles. This ice shows very little electrification upon melting. Water which is freed of dissolved gases and is subsequently frozen in an atmosphere of air, nitrogen, or oxygen produces ice containing many tiny gas-bubbles, and this ice upon melting is accompanied by electrification. These facts provide evidence that the entrapped gas-bubbles are negatively charged and, upon melting, these bubbles are free to rise to the surface and escape, thus carrying negative charge from the water and leaving the water with a net positive charge. The experiments described above indicate that the presence of impurities such as dissolved HCl, $NaOH$, and KCl decrease, and with sufficient concentration, completely stop the electrification of the melting water. Ice frozen from tap-water contains sufficient impurities so that no electrification occurs when it melts. It was also observed that distilled water, which was boiled in a pyrex container, became contaminated to the extent that ice frozen from this water showed a greatly reduced electrification upon melting.

It was first observed by Quincke [9] that there existed an electrification of liquid-gas interfaces. McTaggart [10, 11] first made measurements on the cataphoresis of gas-bubbles. The apparatus used by McTaggart consisted essentially of a piece of glass tubing about 25 cm in diameter and seven cm long, closed at each end by a platinum electrode having pivot-points on which the cell was rotated by an electric motor. The cell was completely filled with water, and a small bubble was introduced. Upon rotation, the bubble assumes a position on the axis of the tube where it remains steady so that its motion along the axis resulting from the application of a potential on the electrodes can be observed by means of a microscope.

McTaggart found that a gas-bubble carried a negative charge. The purity of the water affected the magnitude of the charge. Using dilute solutions of HCl it was found that, upon increasing the concentration, the negative charge on the air-bubble was reduced until it was practically zero. No reversal of sign was found in the highest concentration that was used.

The presence of alcohol in the water was found to reduce the electric charge carried by the bubble.

Alty [12] using McTaggart's method for the study of the cataphoresis found that the charge is independent of the gas when using helium, acetylene, and oxygen. The use of carbon dioxide showed a greatly reduced charge, and it was concluded that the reduced electrification results from the formation of a weak solution of carbonic acid.

Currie and Alty [13] found that the charge on a bubble was independent of the size of a bubble having a radius above a critical value; however, below this value the charge fell off with size of bubble. In very pure water the charge per bubble was found to be 5.4×10^{-4} esu above the critical radius of 0.033 cm.

In more recent experiments McTaggart [14] has shown that it is possible to reduce and reverse the sign on a gas-bubble by very weak solution of thorium nitrate.

The charge acquired by a bubble is due to the selective absorption of ions by the surface molecules. The surface of the bubble is considered to consist of water molecules which are partly or completely orientated. These, owing to their polar nature, have a resultant field and therefore attract ions of one sign while repelling those of the opposite sign. In the case of water, the orientation is such as to attract negative ions from the water. These ions are absorbed on to the surface of the bubble and give it a negative charge. At the same time, some of the negative ions already absorbed will be removed by the thermal agitation of the liquid and a state of equilibrium will eventually be reached in which the number striking the surface per second is equal to the number re-evaporated from it. This absorption of negative ions is accompanied by the capture of positive ions from the liquid. Any such positive ion striking an absorbed negative ion may be bound to it by the electrostatic attraction so that a number of the negative ions are covered by positive ions and the charge on the bubble is due to the remaining uncovered negative ions.

It appears, therefore, that the electrification accompanying the melting of ice is coupled with the same phenomena observed in the cataphoresis of air-bubbles in water. The dissolved gas in the water is forced out of solution upon freezing and entrapped in the ice. The bubble acquires a negative charge by the mechanism described above either at the time the ice is frozen or at the moment the bubble is released from the ice into the liquid during the melting process. In either event when the ice melts the charged bubble is free to rise to the surface and upon bursting, the charge in some manner is released to the atmosphere, thus giving a negative charge to the air above and leaving the water with a net positive charge.

The charge per bubble as indicated in Column (7) of Table 1 is considerably smaller than that indicated by Currie and Alty for bubbles in pure

water; however, the radius is much smaller than the critical radius, but Currie and Alty indicated that the charge falls off with size of bubble below the critical radius. It is to be pointed out that the assumption made in Column (3) and the measurements recorded in Column (2) are only approximate, so that the calculated values in Columns (4), (5), (7), and (8) can merely be rough approximations.

The fact that the purity of the water and also additions of weak concentrations of HCl and alcohol reduce the electrification in the studies made on the cataphoresis is also in agreement with the observations given in this paper. The cataphoresis experiments indicate a reversal of sign under certain conditions; however, no reversal of sign was ever experienced in the present observations.

The observation that the rate at which the ice is frozen affects the amount of electrification upon melting may be accounted for by the fact that rapid freezing entraps a greater number of bubbles as is evidenced by the translucent appearance of the ice. However, a slow rate of freezing produces ice which is more nearly transparent because of the reduced number of entrapped bubbles.

Relation of entrapped air electrification to phenomena of thunderstorms

The suggestion has frequently been made that the separation of electrical charge in thunderstorm-activity is closely related to a change of state of the snow falling into the lower and warmer regions.

The specific electrification measured above is so large that it could easily account for phenomena of thunderstorms provided the snow falling into the warmer regions contained entrapped air. Unpublished data collected in aircraft do not suggest that the process is very important in conditions of ordinary rain or thunderstorm. It is recognized, however, that in the process of forming hail, the layer-by-layer freezing process will entrap many air-bubbles. It is therefore suggested that the mechanism considered above will be important in areas where melting hail exists. A positive charge of 1.25 esu/gm of water melted is sufficiently large that electric fields as great as those commonly encountered in thunderstorms may reasonably be expected [1]. A more detailed discussion of this phenomenon awaits the reduction and analysis of already available data secured in aircraft flying in fronts and in thunderstorm areas.

Summary

The following statements summarize the observations presented in this paper:

(1) A change in contact-potential accompanies the freezing of the surface of pure water. This change is transient in nature, that is, the

contact-potential of an ice-air surface returns to the same value as a water-air surface after a period of time.

(2) Air passing over melting ice acquires a negative charge. The charge acquired is approximately 1.25 esu per cc of melted ice.

(3) A positive charge is acquired by melting ice. This charge is of the order of 1.25 esu per cc of water.

(4) The presence of impurities such as a weak concentration of HCl, NaOH, and KCl greatly reduces and, with sufficient concentrations, completely prohibits the charging-effect to accompany the melting of the ice.

(5) A rapid rate of freezing and melting somewhat enhances the charging-effect.

(6) The presence of dissolved gases in the water before freezing is necessary to produce the electrification of the melting ice. The dissolved gases are forced out of solution during freezing and are entrapped in the ice in the form of small bubbles. Upon melting, these bubbles are negatively charged and rise to the surface releasing charge to the air above.

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Naval Research Laboratory,
Washington 20, D. C., July 23, 1946

RECORDS OF THE IONOSPHERE DURING THE TOTAL ECLIPSE IN THE NORTH OF SWEDEN ON JULY 9, 1945

By W. Stoffregen

An expedition was sent from the Institute for High-Tension Research, University of Uppsala, for ionospheric investigations together with research on thunderstorms and atmospherics during the total eclipse on July 9, 1945. The observations were made at Hörnsjö (latitude = 63°.82 north, longitude = 19°.56 east). The times of first contact, maximum obscuration, and last contact were $13^h51^m.6$, $15^h01^m.5$, and $16^h07^m.7$, respectively. Hörnsjö is situated vertically below the central-line of the eclipse at about 100-km height of the *E*-region.

A portable ionosphere-recorder of small dimensions (70 by 50 by 35 cm) was used. This instrument is automatic and covers a frequency-range of 1.5 to 10 Mc/sec. The recorder is shown in Figure 1.

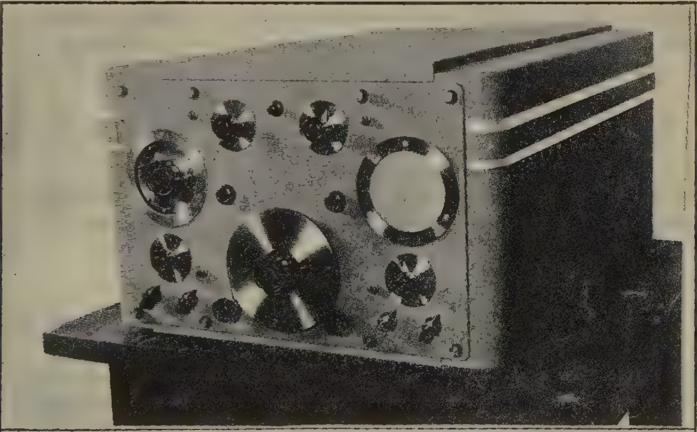


FIG. 1—PORTABLE AUTOMATIC IONOSPHERIC-RECORDER FOR FREQUENCY-RANGE OF 1.5 TO 10 MC/SEC

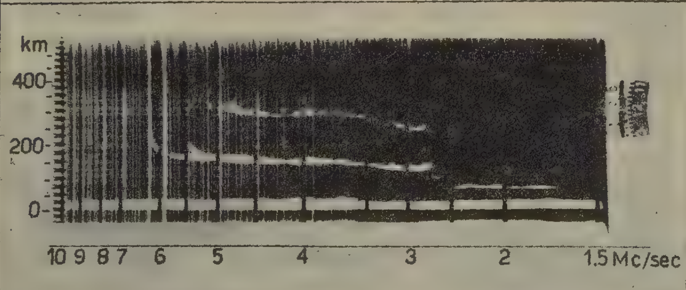


FIG. 2—TYPICAL RECORD WITH TIME-, FREQUENCY-, AND HEIGHT-MARKINGS

The transmitter, receiver and cathode-ray unit with power-supplies and the photographic recorder are assembled together in this apparatus. Each record takes five minutes and is started automatically at any predetermined time by adjustment of the clock. The date and time are photographed on each record, as likewise the frequency- and height-markings. A typical record is seen in Figure 2.

Earlier observations during solar eclipses have shown that the variations of ionization in the $F2$-, $F1$- and E-layers are different according as the eclipse occurs in summer or winter. According to Berkner [see 1 of "References" at end of paper] the $F2$-region does not show any great influence due to the eclipse when the $F1$- and $F2$-regions are well separated, which is the case in summer. The influence is more decided when the $F1$-

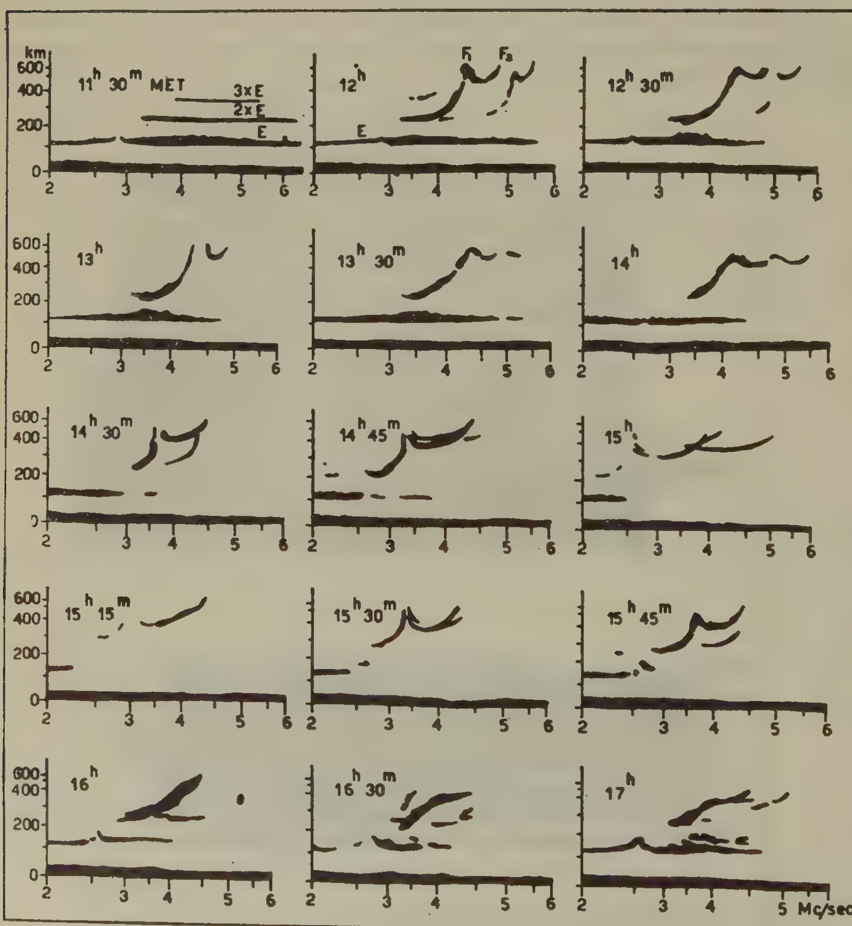
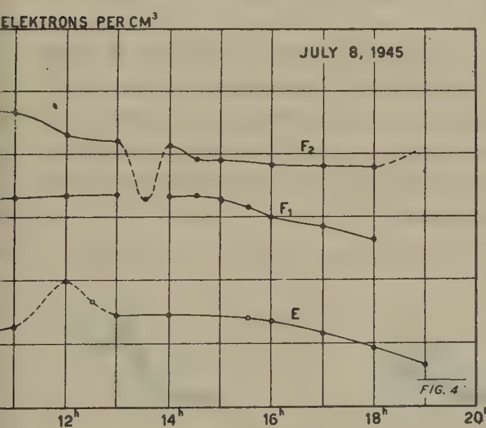


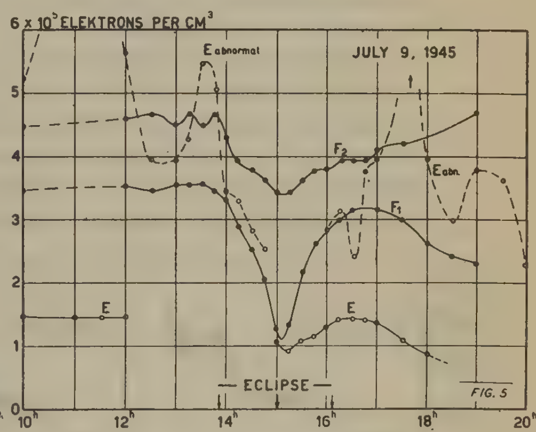
FIG. 3—RECORDS ON JULY 9, 1945, INCLUDING PERIOD OF ECLIPSE

and $F2$-regions merge, as is the case in winter. The results of this eclipse agree with this point of view. The effect upon the $F2$-layer was marked but the measured decrease in ionization is not more than about 25 per cent. For comparison with some earlier results in different seasons it may be mentioned that no significant decrease in the $F2$-region's ionization was observed by Kirby, Berkner, Gilliland and Norton [2] during the eclipse of August 31, 1932, and by Minohara and Ito [3] during the eclipse of June 19, 1936. Observations during the eclipse of February 3, 1935 [4] showed a large decrease in the ionization of the $F2$-region.

The $F1$-region's ionization decreased about 66 per cent and increased again following nearly the course of the eclipse. A small delay of about five minutes was observed between the minimum of ionization and totality.

The situation in the E-region was more complicated. The day before the eclipse considerable geomagnetic activity was reported. On July 9, no magnetic disturbances of importance were present, but thunderstorms





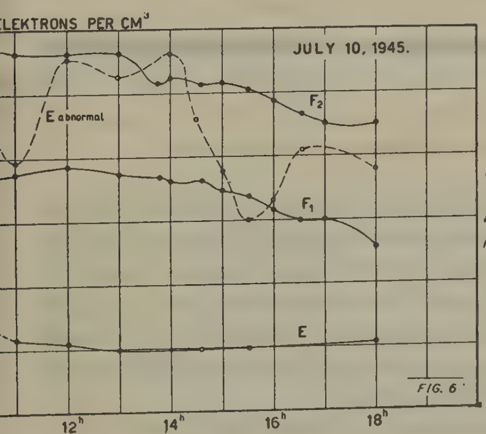


FIG. 4—VARIATION OF IONIZATION ON JULY 8, 1945 ($N = 1.86 \times 10^4 \times f^2$ ELECTRONS/CC, f = FREQUENCY ORDINARY RAY IN MC/SEC)

FIG. 5—IONIZATION DURING JULY 9, 1945, DAY OF ECLIPSE.

FIG. 6—IONIZATION DURING JULY 10, 1945

occurred near the place of observation both on July 8 and on the morning of July 9. On records before the eclipse, strong E-abnormal ionization was observed, as shown by Figure 3 in the record at 11^h30^m with only repeated E-reflections. The nearness of thunderstorms may have contributed to this abnormal E-ionization. Copies of other records on July 9 are also given in Figure 3. The E-layer showed high abnormal ionization and on the graphs in Figures 5 and 6 these values are marked as dotted lines.

Values for normal critical frequencies have been difficult to get from the records. In a few cases irregularities on the E-reflections gave some values as seen in Figures 5 and 6. The effect of the eclipse was evident, no abnormal E-reflections were noted during the greatest part of the eclipse. The decrease of ionization of the normal E-region is about 30 to 40 per cent.

Variations of height have been observed during eclipses of earlier date. Naismith [5] observed a rise from 300 to 600 km. In an earlier paper [6] the author described an observed rise of the $F2$-region of about 12 per cent during the eclipse on September 10, 1942, when the obscuration was about 46 per cent near the ground.

The variations of height are seen from the records in Figure 3. The $F2$-region showed a typical rise at 15^h and $15^h\ 15^m$, estimated at 60 per cent.

The values for the control-days July 8 and 10 are given in Figures 4 and 6. The E-, $F1$- and $F2$-regions showed a quite normal tendency except the situation about 13^h30^m on July 8. This effect may be explained by the presence of important geomagnetic disturbances.

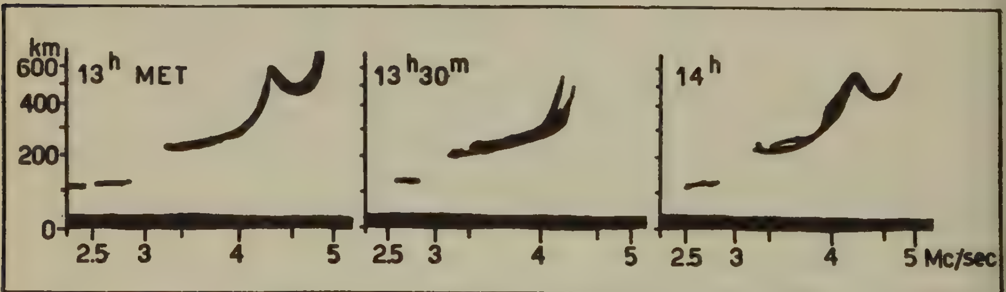


FIG. 7—RECORDS ON JULY 8, 1945, DURING DISTURBANCE IN F2-LAYER AT 13^h30^m

Summary—Observations during the total eclipse of July 9 in northern Sweden were made with a portable ionospheric recorder. Some of the records obtained are reproduced in order to show details of changes during the eclipse. The variations of the E-, $F1$- and $F2$-ionization are given in graphical form and agree with earlier observations. The variations were nearly symmetrical with the eclipse. The abnormal E-ionization disappeared completely during the latter part of the eclipse.

The $F2$-region showed a marked increase in height during the eclipse.

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Uppsala, Sweden, July 1946

LETTERS TO EDITOR

(See also pages 556 and 577)

PROVISIONAL SUNSPOT-NUMBERS FOR JULY TO SEPTEMBER, 1946

(Dependent alone on observation at Zürich Observatory)

Day	July	August	September
1	96	153	115
2	106	154	128
3	91	137	127
4	104	137	97
5	120	128	63
6	120	111	49
7	99	116	49
8	88	100	49
9	79	109	40
10	60	107	50
11	76	99	49
12	91	98	68
13	87	86	92
14	80	108	89
15	78	95	100
16	89	109	95
17	107	90	90
18	124	94	99
19	150	100	100
20	130	107	90
21	110	110	88
22	143	104	101
23	137	115	133
24	146	107	109
25	117	94	139
26	120	80	132
27	171	73	152
28	156	82	129
29	157	88	105
30	165	114	93
31	174	119	
Means........	115.2	107.2	94.0
No. days......	31	31	30

Mean for quarter July to September, 1946: 105.6 (92 days)

Swiss Federal Observatory,
Zurich, Switzerland

M. Waldmeier

FREQUENCY OF 12,330 MEASURED HEIGHTS OF AURORA FROM SOUTHERN NORWAY IN THE YEARS 1911-1944

By Carl Störmer

(1) Since 1911, I have had at my disposition a network of auroral stations in southern Norway and about 32,000 usable auroral photographs have been taken. Among these are several thousand taken simultaneously from two or more stations to determine the height and situation of the aurora. The results obtained during 1911-22 are described in *Geofysiske Publikasjoner* [see 1 of "References" at end of paper]. Since 1922 only selected auroras have been measured.

In 1928 a list of the number of successful photographs since 1922 was given [3]; Table 1 summarizes these for this period and also those obtained since then. The headings of Table 1 have the following meanings: N is the number of nights on which photographs of aurora were taken; I is the num-

Table 1—*List of aurora photographs taken in southern Norway from 1923-1945*

Year	N	I	II	III	IV	Sets	Σ	n
1923	1	19	31	5	....	36	96	6
1924	2	3	6	....	....	6	15	2
1925	6	54	42	2	....	44	144	7
1926	15	190	185	26	....	211	638	6
1927	2	26	44	3	....	47	123	6
1928	11	156	98	68	7	173	584	6
1929	14	89	158	100	80	338	1025	4
1930	14	106	162	85	6	253	709	4
1931	7	92	66	39	4	109	357	5
1932	5	32	21	19	8	48	163	5
1933	22	401	347	108	7	462	1447	9
1934	13	188	63	80	9	152	590	7
1935	17	485	216	92	39	347	1349	7
1936	22	759	334	243	44	621	2332	10
1937	17	612	188	149	81	418	1759	9
1938	42	2486	735	540	154	1429	6192	10
1939	39	1529	254	101	8	363	2372	8
1940	39	2261	263	138	28	429	3313	10
1941	36	2361	445	187	46	678	3996	6
1942	24	706	251	220	57	528	2096	5
1943	12	542	89	90	22	201	1078	6
1944	8	166	29	....	....	29	224	5
1945	9	282	48	16	6	70	450	6
Total	377	13545	4075	2311	606	6992	31052	

ber of single photographs taken; II, III, and IV are the numbers of sets of photographs taken simultaneously from 2, 3, or 4 stations; the Column marked "Sets" is the total of II, III and IV; Σ is the total number of photographs that is, (I + 2 × II + 3 × III + 4 × IV); n is the number of auroral stations in action.

Of the sets giving height and situation of the auroras, the computations for about one-half have been completed and have given more than 10,000 heights. The measured auroras are spread over all years from 1923 to 1945. A detailed examination of all negatives has shown that about 8,000 more heights can be found from the same material and the work is under way.

The numerous auroral heights already determined, together with the heights measured in 1911-22, total now 12,330, are enough to give interesting statistical results.

This statistical work is in progress but it may be of interest to give now the distribution of all the heights hitherto measured. These heights are of points on the aurora partly at the lower and partly at the upper parts, and partly at places between the upper and lower parts. The results thus give an impression of the occurrence of aurora in the atmosphere. The frequency of heights for different levels is shown in Table 2.

TABLE 2—*Auroral height-frequencies for various intervals of height*

Interval	No.	Interval	No.	Interval	No.	Interval	No.
km km		*km km*		*km km*		*km km*	
70– 79	58	230–239	246	390–399	111	550– 559	24
80– 89	393	240–249	197	400–409	96	560– 569	31
90– 99	1280	250–259	216	410–419	88	570– 579	28
100–109	1808	260–269	203	420–429	87	580– 589	22
110–119	1304	270–279	192	430–439	69	590– 599	20
120–129	544	280–289	183	440–449	70	600– 649	80
130–139	397	290–299	181	450–459	64	650– 699	48
140–149	291	300–309	183	460–469	59	700– 749	24
150–159	266	310–319	137	470–479	50	750– 799	14
160–169	291	320–329	153	480–489	50	800– 849	12
170–179	296	330–339	148	490–499	63	850– 899	7
180–189	291	340–349	132	500–509	41	900– 949	1
190–199	282	350–359	135	510–519	46	950– 999	0
200–209	301	360–369	121	520–529	33	1000–1049	2
210–219	299	370–379	127	530–539	29	1050–1099	3
220–229	273	380–389	110	540–549	20		
						Total	12330

The frequency of the heights is well illustrated in Figure 1. For each km the measured heights are distributed as points along the corresponding

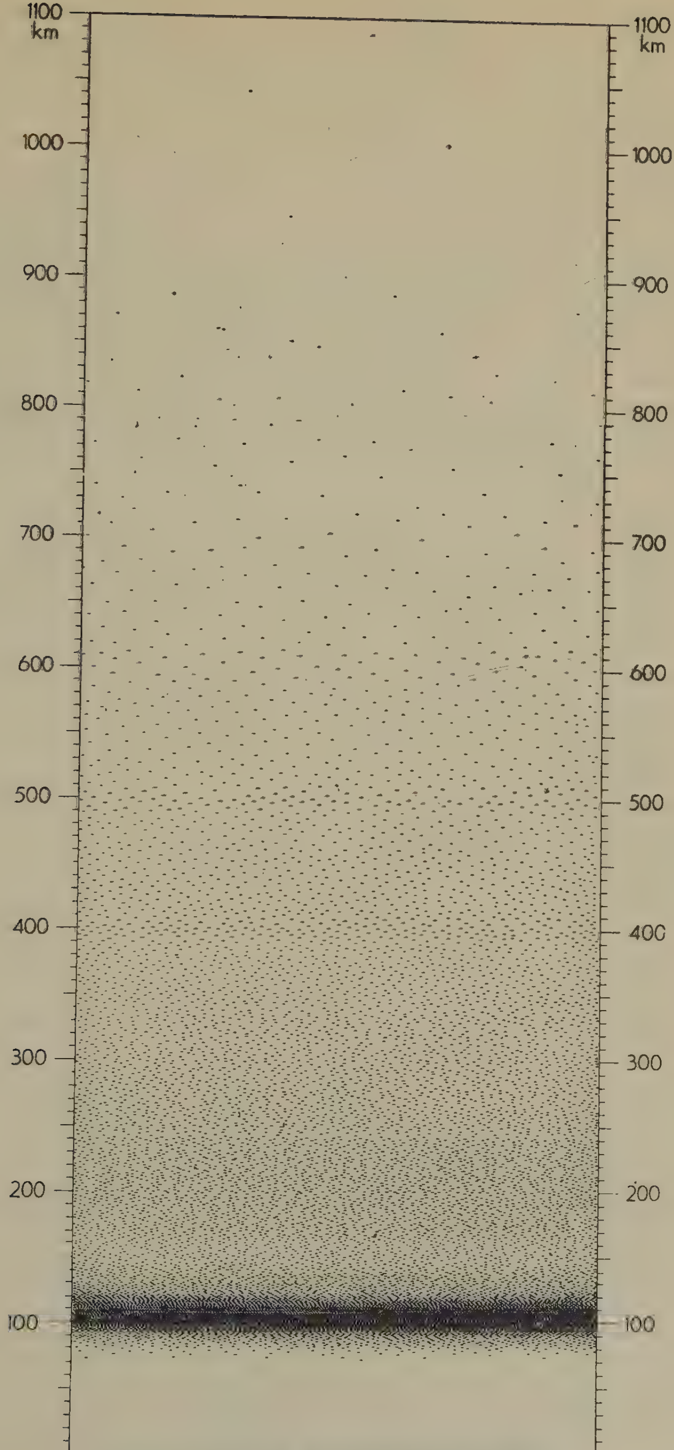

FIG. 1—THE VERTICAL DISTRIBUTION OF THE AURORA

horizontal line at approximately equal distances. In the height-interval 90-110 km the points are so crowded that they can hardly be distinguished individually.

The detailed statistical treatment of the material is being made but takes much time, because the distribution of the heights must be examined from various points of view. Of particular interest are the heights of the *lower border* for the different auroral forms, such as arcs, bands, curtains, rays, and so on and their variation with geographical situation and with geomagnetic latitude and longitude. Furthermore, it will be of interest to study variations with local time, with season, and with the periods of solar activity, as also with dark and sunlit atmosphere and with possible tides in the upper atmosphere [4]. The results of these researches will be published as soon as possible.

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Institute of Theoretical Astrophysics,
Blindern, Oslo, Norway, July 5, 1946

AMERICAN MAGNETIC CHARACTER-FIGURE, C_A, THREE-HOUR-RANGE INDICES, K, AND MEAN K-INDICES, K_A, FOR JULY TO SEPTEMBER, 1946

By W. E. Scott

Summaries of American *URSI* broadcasts have appeared regularly in this Journal since the issue for December, 1930.

Table 1—*American magnetic character-figure C_A for Greenwich half- and full-days based on reports from Cheltenham, Honolulu, Huancayo, San Juan, Sitka, Tucson, and Watheroo for July to September, 1946*

Day	July			August			September		
	0^h-12^h	12^h-24^h	0^h-24^h	0^h-12^h	12^h-24^h	0^h-24^h	0^h-12^h	12^h-24^h	0^h-24^h
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.2	0.1	0.1	0.0	0.0	0.0	0.4	0.0	0.2
3	0.7	0.1	0.4	0.0	0.1	0.0	0.0	0.3	0.1
4	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.4	0.5
5	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.2	0.2
6	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0
7	1.1	0.7	0.9	0.5	0.6	0.6	0.5	0.6	0.5
8	0.3	0.5	0.4	0.1	0.2	0.2	0.4	0.2	0.3
9	0.9	0.5	0.7	0.1	0.0	0.0	0.1	0.6	0.4
10	0.1	0.2	0.1	0.0	0.1	0.1	0.6	0.3	0.4
11	0.6	0.2	0.4	0.7	0.9	0.8	0.2	0.4	0.3
12	0.1	0.0	0.1	0.5	0.3	0.4	0.3	0.3	0.3
13	0.0	0.0	0.0	0.3	0.2	0.2	0.0	0.1	0.1
14	0.3	0.9	0.6	1.0	0.9	0.9	0.0	0.0	0.0
15	0.6	0.1	0.4	0.6	0.7	0.7	0.0	0.0	0.0
16	0.1	0.4	0.3	0.5	0.7	0.6	0.0	1.1	0.6
17	0.6	0.4	0.5	0.7	0.6	0.6	0.7	0.6	0.6
18	0.2	0.9	0.6	0.0	0.0	0.0	1.8	1.6	1.7
19	1.0	0.4	0.7	0.0	0.1	0.0	1.3	1.1	1.2
20	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.2	0.3
21	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.9	0.4
22	0.1	0.3	0.2	0.0	0.0	0.0	1.9	2.0	2.0
23	0.5	0.6	0.5	0.0	0.0	0.0	1.8	1.6	1.7
24	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.3	0.5
25	0.5	0.8	0.6	0.0	0.0	0.0	0.0	0.0	0.0
26	0.6	1.8	1.2	0.0	0.0	0.0	0.0	0.0	0.0
27	2.0	0.6	1.3	0.0	0.0	0.0	0.6	0.9	0.8
28	0.1	0.7	0.4	0.0	0.0	0.0	1.1	1.4	1.3
29	1.1	1.0	1.1	0.0	0.0	0.0	0.8	0.6	0.7
30	0.9	0.7	0.8	0.0	0.4	0.2	1.0	0.6	0.8
31	0.1	0.1	0.1	1.3	0.6	0.9			
Means	0.4	0.4	0.4	0.2	0.2	0.2	0.5	0.5	0.5

Table 2--Three-hour-range indices, K, July to September 1946

July 1946

	1	2	3	4	5	6	7	8
Si	1100 1110	1333 3221	3345 4111	2103 3100	0000 1100	2112 2111	2646 5545	5435 3312
Ch	1001 1111	1332 2222	3344 3222	2201 1001	1000 1111	2111 2222	3555 3244	3223 3322
Tu	1001 1111	1334 3222	3443 3222	2212 2211	1111 1211	2011 2222	3555 4544	5224 4422
SJ	0000 0100	0221 1101	2343 2120	0100 0000	0000 1000	1000 0111	1545 3333	2113 3531
Ho	0100 0002	1221 2012	2232 2211	2101 2011	1000 0210	1100 0012	2444 2222	3103 3411
Hu	0000 1210	0221 2211	2233 3320	0102 2210	0000 2200	1011 2311	1444 3532	3112 4510
Wa	0011 1110	1222 2211	2343 2211	1113 3110	1111 1111	1111 1221	1444 2335	2223 3322
	9	10	11	12	13	14	15	16
Si	4323 3332	3223 1333	3333 2231	2342 2110	0002 2111	0234 7422	3523 2221	1014 3323
Ch	4334 2343	3113 1323	4432 2333	1221 2121	0112 1112	1234 5433	2422 2222	1014 2433
Tu	5435 2343	3322 2324	3333 2233	2331 2121	0102 1123	1243 5443	4532 1321	2013 3433
SJ	5334 1132	3102 1322	2223 1231	0010 2210	0001 0011	0133 4422	2421 1220	0013 2322
Ho	4234 1232	0203 1202	4212 0112	2130 0211	1002 1212	1222 4322	2442 2001	1003 2212
Hu	3324 3442	2102 3322	2222 3441	1211 1220	0001 1211	0122 3642	2421 2331	1003 3432
Wa	4234 3232	1112 1422	2322 2122	1121 1111	1112 2111	1233 5411	2431 1211	1114 3422
	17	18	19	20	21	22	23	24
Si	4344 4211	2223 3544	4566 6322	2200 0122	3221 1222	3332 3223	3325 4323	1110 2010
Ch	4344 2322	2213 4444	5544 3122	1200 1123	2222 2324	1422 1233	4324 3334	1112 2112
Tu	4344 3322	2224 4533	5445 4132	3200 1123	2322 2433	3432 2224	4334 3323	2221 2113
SJ	3232 1211	2113 4443	4333 3010	1100 0113	2222 2323	1411 2233	3223 2432	1101 2112
Ho	3343 3132	1013 4432	3334 3122	2200 0222	1211 0112	2221 2112	3224 2221	3211 1221
Hu	3222 2321	1113 5552	4323 4321	1200 2321	1211 3522	2311 3442	3224 3432	1102 2311
Wa	3332 3222	2224 4544	3233 5233	2211 0021	1122 2212	1311 3332	3324 3221	1222 3121
	25	26	27	28	29	30	31	
Si	3334 2334	4433 3287	9997 6332	3313 4444	5565 6753	5444 6322	4112 2212	
Ch	2234 1444	3332 3387	9985 4333	2222 3344	5643 3544	5543 4433	3212 1112	
Tu	3333 1544	5433 2397	8875 3333	4222 3454	5653 4654	5544 3533	3212 2423	
SJ	2321 2553	4422 3377	8764 3222	1111 2123	4543 2533	5533 3222	2101 0001	
Ho	2223 0342	3222 2277	7654 3333	1110 2233	4433 3433	4333 4222	2000 0111	
Hu	1222 3642	3422 3476	7764 4432	1112 4433	4433 3653	4423 4431	2101 2300	
Wa	1223 1222	3323 2277	8775 3221	2232 3133	4543 2543	5435 5312	3211 0101	

August 1946

	1	2	3	4	5	6	7	8
Si	3221 2221	1112 1121	1111 0000	1000 0110	1011 1111	2012 3112	3332 5531	2210 0221
Ch	2111 1121	1111 1021	1222 1011	1110 0121	0022 2121	1112 3012	3431 3332	3210 0332
Tu	2121 2222	2201 1122	2211 1121	1111 1122	1022 2123	2113 3222	3332 4433	3220 1333
SJ	1101 1110	0000 0000	0100 2321	1112 2132	2113 2321	1112 3332	3323 4433	2210 1323
Ho	1000 0223	1000 1011	1100 0122	1110 1110	1012 1121	1102 1101	2222 2231	2210 0312
Hu	1101 0221	0000 2230	0210 2320	1111 2220	1011 2320	1111 3221	3222 4542	2211 2431
Wa	2111 1111	1111 1111	1112 1111	1121 1111	1122 2111	1211 2111	3344 5452	2221 1222
	9	10	11	12	13	14	15	16
Si	3100 1110	0001 1123	3443 4323	3242 0222	3231 1121	2358 7334	4333 2333	3335 2243
Ch	3112 1122	0001 1233	4443 4343	3231 1224	3231 0143	2355 3245	4523 3333	4332 2244
Tu	3112 1122	1001 1233	3453 4444	4252 1214	3331 1242	3354 3244	5423 3334	4333 2354
SJ	3002 1222	0001 0112	2343 3323	3231 0112	2221 0032	2244 2234	4313 1232	3222 1153
Ho	3102 1212	0001 0211	2443 4223	3141 0113	2220 0132	2243 2133	5312 1122	2223 0232
Hu	3102 1321	0001 2331	2342 5442	3231 2322	2210 2332	2233 3443	3212 4542	3220 3443
Wa	2111 0221	1111 1122	2342 4443	3232 1114	3221 1131	2355 5344	4223 2443	2324 1154
	17	18	19	20	21	22	23	24
Si	3476 4422	2032 1122	3211 1121	2302 1011	1111 0000	1100 0001	0000 0000	2220 0121
Ch	1455 4223	1121 1122	3211 2132	2201 2011	1101 0011	1200 0010	1000 0001	2231 1122
Tu	3454 4323	2121 1122	3222 2222	2310 1111	2111 1112	1100 0000	1000 1000	1241 2123
SJ	2444 3324	0001 3222	2210 0022	2201 2221	1001 2121	0100 1100	0000 0001	1130 0112
Ho	1153 2112	1011 0111	3010 0112	1200 1100	1100 0002	1000 0011	0100 0100	1330 1112
Hu	1232 5432	1001 2321	1110 3331	1200 2220	0100 1110	1100 0100	0000 1100	1230 2322
Wa	1333 4323	1021 1111	3110 0012	1211 0210	0111 0000	0101 0000	0011 0001	1131 1112
	25	26	27	28	29	30	31	
Si	2200 0100	1000 0010	0222 2001	2200 1120	0000 0000	0000 0023	4864 6321	
Ch	3210 1011	1000 0020	1321 1013	1100 1130	1110 0011	0000 0035	4663 3333	
Tu	3321 1211	2000 0121	1332 2113	2200 1221	2110 0111	0000 0134	5653 4322	
SJ	3311 0100	0000 0020	0111 0001	0100 0210	0000 0000	0000 0034	5552 4322	
Ho	2211 0112	1000 0111	0221 1011	0100 0021	1000 0011	1000 0134	4662 4222	
Hu	2110 2310	0000 1230	0111 2211	1100 2331	0000 0210	0001 1344	3432 4542	
Wa	2212 0000	1222 1111	1221 2112	1211 1121	1110 0211	0000 0124	3554 4321	

¨Interpolated

Table 2--Three-hour-range indices, K, July to September 1946--concluded

September 1946

	1	2	3	4	5	6	7	8
Si	1001 2100	3240 0122	2012 1112	3237 5222	1144 4321	2310 0000	0135 6331	2144 3122
Ch	1012 2111	3142 0022	2110 0223	2344 1133	2132 3212	2410 0000	0235 3233	2123 1123
Tu	2011 2112	2241 1123	2111 1214	3345 3223	3133 4322	3420 0001	0243 4232	2133 2232
SJ	1001 3221	2231 2321	2011 1233	3233 3232	2122 2221	2410 1001	1223 3233	2131 2032
Ho	1001 1112	2120 0022	1011 1122	2225 3112	2113 1100	2210 0022	1143 3222	2143 2232
Hu	0001 3311	2231 1221	1000 2443	2223 3331	1112 3421	2311 1100	0133 4442	2231 2332
Wa	1112 1221	2142 1231	2111 2222	2235 3222	2223 2311	2211 0000	1144 4232	2222 3133
	9	10	11	12	13	14	15	16
Si	2211 3333	3155 3212	2124 1222	2143 4211	1200 1121	2032 1111	1131 0211	0000 3553
Ch	3312 3333	2144 2124	2123 2233	2142 2223	2411 1222	2022 0132	1221 1332	2112 3454
Tu	3321 3443	2144 3234	2223 2333	2142 3133	2321 2232	3032 1133	1231 2312	1111 3555
SJ	3311 1333	2033 2213	0212 2222	1122 2221	1201 2012	1011 1112	1120 1121	0000 4554
Ho	2311 1332	2133 2113	1213 2022	1112 2223	2310 0123	2112 1122	1120 0111	2101 3454
Hu	2311 4452	2123 3312	2212 3432	1222 3331	1212 3331	2121 2222	1122 3421	1102 5654
Wa	2321 2352	3244 4223	2223 2332	2233 3122	1311 1121	1111 1021	2221 0221	1111 3455
	17	18	19	20	21	22	23	24
Si	4425 3213	7798 9864	6656 8723	3233 0222	2112 2433	3889 9955	7897 8965	5345 4220
Ch	6422 1236	6777 6655	5544 5433	2243 0222	3112 2544	4779 9965	6784 6656	5433 3221
Tu	5433 2234	6666 6554	5645 6544	3233 0132	2112 2545	3779 9855	7774 5645	4433 3211
SJ	4411 0224	7564 5455	5533 4322	1120 0121	1001 1435	3657 8755	5653 5545	4222 3210
Ho	3333 1224	7546 5544	5525 4323	2232 0212	1102 1433	2767 8644	6564 4533	2243 2311
Hu	4312 2435	6655 6664	5533 6632	2221 2442	1002 3653	3557 9964	5553 6654	3213 3420
Wa	3332 2335	6556 6764	4434 8443	3132 1132	2213 2544	2778 9964	6665 5765	4334 3221
	25	26	27	28	29	30		
Si	0001 1011	0033 2201	2156 5553	3687 8865	5343 5442	3557 5333		
Ch	2111 1021	0213 2222	3244 3444	4555 5556	6421 2333	5545 3242		
Tu	2011 1011	0023 2213	3345 4554	5555 6534	5532 3334	5544 4443		
SJ	0000 0000	0011 1102	2122 3345	4454 4334	5221 1231	3533 2232		
Ho	0101 0011	0112 1112	3144 3333	3444 5433	4321 2222	3334 3232		
Hu	0000 1211	0112 3312	2122 5553	4444 5655	4221 3442	3422 3432		
Wa	0111 1121	1112 2212	2234 4654	3454 7665	4342 4443	3425 2542		

¨Interpolated

Table 3--Weighted average of reduced three-hour-range indices, July to September 1946

Day	July 1946									August 1946									September 1946								
	Values K_A								Sum	Values K_A								Sum	Values K_A								Sum
1	0x	0x	0	0x	1	1	0x	0x	4x	2	1	1	1	1	1x	1x	1	10	1	0	0x	1x	2	1x	1	1	8x
2	1	2x	2x	2	2	1x	1x	1x	14x	1	1	0x	1	1	0x	1x	1	7x	2x	1x	3x	1	0x	1	2	1x	13x
3	2x	2x	3x	3x	2x	2	1x	1	19	1	1x	1	1	1	1	1	1	8x	2	0x	1	1	1	2	2	2x	12
4	1x	1	0x	2	2	0x	0x	0x	8x	1	1	1	1	1	1	1x	1	8x	2x	2x	3	4x	3	2	2	2	21x
5	1	0x	0x	0x	1	1	0x	0x	5x	1	0x	1x	2	2	1x	1x	1	11	2	1x	2x	2x	3	3	1	1	16x
6	1x	1	1	1	1x	1x	1x	1x	10x	1x	1	1	2	2x	1x	1x	1x	12x	2	3	1	0x	0	0	0x	0x	7x
7	2	4x	4	4x	3	3x	3x	4	29	3	2x	2x	2x	4	4	3x	2	24	0x	1x	3x	4	3x	2x	3	2	20x
8	3x	2	1x	3	3	3x	1x	1x	19x	2x	2	1x	0x	0x	3	2x	2	14x	2	1x	3	2x	2	1x	2x	2x	17x
9	4	2x	2x	4	2	2x	3x	2	23	3	1	0x	1x	1	1x	1x	1	11	2x	3	1x	1x	2x	3x	3x	2x	20x
10	2	1x	1	2x	1x	3	2	2x	16	0x	0	0	1	1	1x	2	2	8	2x	1x	3x	3x	3	2	1x	3	20x
11	3	2x	2	2x	1x	2	3	2	18x	2x	3	4	3	4	3x	3	3	26	2	2	2	3	2	2x	2x	2x	18x
12	1x	1x	2	1	1x	1x	1x	0x	11	3	1x	3x	1x	0x	1x	1x	3	16	2	1x	3	2x	3	2	2	2	18
13	0x	0x	0x	2	1	1	1	1x	8	2x	2	2	1	0x	1	3	1x	13x	1x	3	1	1	1x	1x	2	1x	13
14	1	1x	3	3	5	4	2x	2	22	2	2x	4x	5	3x	2x	3x	4	27x	2	0x	2	1x	1	1	2	2	12
15	2x	4	2x	2	1x	2	1x	1	17	4	3	2	3	2	3	3x	2x	23	1x	1x	2x	1	1	2x	1x	1x	13
16	1	0	1	3x	2x	3x	2x	2x	16x	3	2x	2x	2x	1x	2	4x	3x	22	1	1	0x	1	3x	4x	5	4x	21
17	3x	2x	3x	3	2x	2x	2	1x	21	2	3	4x	4	3x	3	2	2x	24x	4x	3x	2x	2x	1x	2x	2x	4x	24
18	2	1x	1x	3x	4	4x	4	3x	24x	1x	0x	1x	1x	1	1x	1x	1x	10x	6x	5x	6x	6x	6x	6x	5x	4x	48
19	4	3x	3x	4	4	1x	2	2	24x	2x	1	1	0x	1	1	2	1x	10x	5	5	3x	4	6	4x	3	3	34
20	2	1x	0	0x	0x	1	2	2	9x	1x	2	0x	1	1x	1	1	0x	9	2x	2	3	2	0x	2	2x	2	16x
21	2	1x	2	2	1x	3	2	2x	16x	1	1	0x	1	0x	0	0x	0x	5	2	1	0x	2	2	5	3x	4	20
22	2	3	2	1x	2	2x	2x	2x	18	1	1	0	0x	0	0	0	0x	3	3	6x	6x	8x	9	8x	5x	5	52x
23	3x	2x	2	4	3	3	2x	2x	23	0x	0	0	0x	0	0	0	0x	1x	6	6	7	4x	5x	7	5	5	46
24	1x	1x	1	1x	2	1	1x	1	11	1x	1x	3	0x	1	1	1x	2	12	4	3	3	3x	3	2x	1x	0x	21
25	2	2	2x	3	1x	4	3x	3	21x	2x	2	1	1	0x	1	0x	0x	9	0x	0x	0x	1	1	0x	1	1	6
26	3x	3	2x	2x	2x	2x	8	7	31x	1	0x	0x	0x	0x	0x	1x	0x	5x	0	1	1x	2x	2	2	0x	2	11x
27	8x	8	7x	5	3x	3	3	2	40x	0x	1x	2	1x	1x	0x	0x	1x	9x	2x	2	3x	4	3x	4x	4x	4	28x
28	2	1x	1x	2	3	2x	3x	3x	19x	1	1x	0	0x	1	1	2	0x	7x	3x	4x	5x	5	6	5x	5	5	40
29	4x	5	4	3x	3	5x	4x	3	33	1	0x	0x	0	0	0x	0x	0x	3x	5	3	3	1x	3	3x	3x	2x	25
30	5	4	3	3x	4	3x	2	2	27	0	0	0	0	0	0x	2x	4	7	3x	4x	3	4x	3	3x	3x	2x	28
31	3	1x	0x	1x	1	1x	0x	1x	11	4	5x	5	3	4	3	2x	1x	28x									

As set forth in this Journal for June, 1937, "The Department of Terrestrial Magnetism and the United States Coast and Geodetic Survey with the cooperation of the United States Army and the United States Navy communication-services and several amateur radio stations have undertaken to supply the American character-figure based upon the reports of the seven American-operated observatories—those of the Department of Terrestrial Magnetism at Huancayo in Peru and at Watheroo in Western Australia, and those of the United States Coast and Geodetic Survey at Cheltenham (Maryland), Honolulu (Hawaii), San Juan (Puerto Rico), Sitka (Alaska), and Tucson (Arizona)." This character-figure is being designated C_A, and its values for the first twelve, the second twelve, and all twenty-four hours of each Greenwich day for July to September 1946, are given in Table 1.

The three-hour-range indices, K, have been compiled since April 6, 1940, for each of the seven American-operated observatories. The eight indices for each day give geomagnetic activity for three-hour periods successively during the Greenwich day. The indices range from "zero" very quiet to "nine" extremely disturbed. The K-indices for Sitka (Si), Cheltenham (Ch), Tucson (Tu), San Juan (SJ), Honolulu (Ho), Huancayo (Hu), and Watheroo (Wa), for July to September 1946, are given in Table 2. Interpolated indices are shown thus: $\bar{3}$.

In the manner set forth in the Journal for September, 1940, the indices are standardized into reduced indices K_r to eliminate local variations. A weighted mean index K_A, is derived from the reduced indices. The reduced indices from Si, Ch, and Wa are given double weight and those from Tu, SJ, Ho, and Hu are given single weight. The weighted indices, K_A, for July to September, 1946, are given in Table 3. A superior cross ($^\times$) following an index-number denotes a half-unit, thus $5^\times = 5.5$, etc.

Department of Terrestrial Magnetism,
Carnegie Institution of Washington,
Washington 15, D. C., October 31, 1946

SUMMARY REPORT ON THE EXTRAORDINARY GENERAL ASSEMBLY OF THE INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS (IUGG), CAMBRIDGE, ENGLAND, JULY 29 TO AUGUST 2, 1946

By J. M. Stagg

The following summary of the proceedings of the Extraordinary Assembly at Cambridge is abstracted from the Report prepared by General Secretary Stagg. The Report will be published in full by the Union, but meanwhile it seems desirable to acquaint readers of the Journal with the proceedings and actions taken.

Delegates—The following countries were represented by delegates: Belgium; Canada; Denmark; France; Great Britain; Holland; India; Indo-China; Italy; Jugoslavia; Morocco; Norway; Peru; Sweden; Switzerland; and the United States of America. Apologies for absence were received from Finland, Greece, South Africa, and Turkey.

Meetings—In the absence, because of illness, of Professor B. Helland-Hansen (Norway), Dr. N. E. Nörlund (Denmark) was unanimously elected Chairman of the Cambridge Assembly.

The delegates met either in full Assembly or in Committee each morning and afternoon from July 29 to August 2, on which day the work of the Assembly was completed by the end of the morning session.

Summary of agenda items and resolutions as adopted

(1) *Report on meeting of the Executive Committee in Oxford, December 1945*—The Assembly agreed to Resolution 1.

Resolution 1: To adopt the Report of the meeting of the Executive Committee of the Union held in Oxford, December 1945.

(2) *Reopening of subscriptions to the Union*—The subjects discussed were (*a*) basis of subscription, (*b*) size of unit of subscription, (*c*) currency in which subscription should be paid, and (*d*) date of introduction of the new basis of subscription. The Assembly adopted the following resolutions:

Resolution 2: That there should be eight categories of membership of the Union, numbered 1 to 8 and that each adhering country should pay annually a number of units of subscription equal to the number of its category of membership. A country offering to adhere to the Union should specify in which category it desired to be classed: the offer to adhere may be refused by the Council of the Union if the proposed category is judged to be manifestly inadequate.

Resolution 3: To adopt the recommendation of the Executive Committee (Oxford) that £100 be the unit for 1946.

Resolution 4: The unit of subscription for 1947 and 1948 should remain at £100.

Resolution 5: To adopt the pound sterling as currency for paying subscriptions until the end of the next Ordinary General Assembly.

As regards item (*d*) see Resolution 20.

(3) *Diplomatic or academic agreement between adhering countries*—On the question of diplomatic convention no formal resolution was adopted but it was agreed to proceed on the basis that the negotiation of a diplomatic convention for the Union was both unpractical and unnecessary, and that the Statutes and Bylaws should be revised on this understanding.

With regard to mode of adherence of countries and organizations to the Union, it was agreed to adopt Resolution 6.

Resolution 6: That each adhering organization shall take such steps as appear most suited to ensure regular payment of subscriptions.

(4) *Policy regarding relations between the Union and United Nations Educational, Scientific, and Cultural Organization* (*UNESCO*)—Resolution 7 was adopted as follows:

Resolution 7: To adopt and approve the draft agreement between the International Council of Scientific Unions (ICSU) and UNESCO as modified at the Assembly of ICSU at London in July 1946.

(5) *Financial responsibility for maintenance of international services of a permanent nature*—The services concerned include Bureau de l'Heure, Isostatic Institute, International Latitude Service, and International Seismological Summary. The discussion resulted in agreement on Resolutions 8 and 9.

Resolution 8: That future financial reports of IUGG should show clearly to what extent Union and Association funds are used for services of a permanent or semi-permanent nature and should contain reasons for continuing these services.

Resolution 9: Having in mind the facilities referred to in Article 7* of the draft agreement between ICSU and UNESCO, the International Union of Geodesy and Geophysics should take early opportunity of those facilities by asking UNESCO to become financially responsible for such services, financed at present by IUGG, as are of a permanent or semi-permanent nature. This financial responsibility should preferably be effected through the Union so that both scientific and financial control may remain with the Union.

*An article of the proposed draft agreement to the effect that UNESCO may from time to time relieve the various Unions of financial responsibility for established international undertakings of a substantial nature, leaving the scientific and technical control of the projects to the Unions.

(6) *Means of increasing the number of countries adhering to the Union*—Now that decision has been reached on important matters like the basis and unit of subscription and the Statutes and Bylaws, Resolutions 10, 11, and 12 were adopted.

RESOLUTION 10: That the USSR be approached by all useful ways in order to secure its adherence to the Union.

RESOLUTION 11: That the phrase "ex-enemy countries" be not used in connection with any country.

RESOLUTION 12: That decisions (about important matters of finance and administration in the Union) be made as early as possible, so that the necessary information about the Union can be provided to countries seeking membership.

(7) *Formation of Committee on the Social Value of the Earth Sciences*—Following discussion on name, functions, and financing of this Committee the Assembly agreed to Resolution 13.

RESOLUTION 13: (*a*) To adopt Oxford Resolution No. 17 on this matter, namely: "A Committee on the Social Value of the Earth Sciences be formed, under the chairmanship of Dr. R. M. Field, with the object of preparing a general statement on the value of the earth sciences for human welfare, and of instituting such forms of publicity as may from time to time be desirable."

(*b*) That a Committee with the title "Committee on the Social Value of the Earth Sciences" be formed.

(*c*) That the Committee be comprised as listed in the Oxford Report (see below) with the addition of the name of Professor Solberg (Norway) and with power to co-opt other members.

(*d*) That the Committee should, for the present, be an independent Committee under the Union.

(*e*) That no serious demands should be made by the new Committee on the funds of the Union.

(*f*) That the Committee be asked to prepare a draft pamphlet outlining the scope and services of the Union for the information of countries whose adherence the Union desires. The final form of the pamphlet will be decided by the Bureau.

The full membership of the Committee is now constituted as follows:

Dr. R. M. Field (USA), Chairman
Prof. C. F. Baschlin (Switzerland)
Prof. G. Cassinis (Italy)
Prof. Sydney Chapman (Gr. Britain)
Dr. Jean Coulomb (France)
Mr. Noel J. Ogilvie (Canada)
Dr. Hans Pettersson (Sweden)
Prof. Jean Rothé (France)
Dr. P. C. Sánchez (Mexico)
Prof. H. Solberg (Norway)

Prof. B. Helland-Hansen (Norway)
Sir G. Lenox-Conyingham (Gr.Br.)
Dr. N. E. Nörlund (Denmark)
Prof. W. T. Thom, Jr. (USA)
Prof. T. G. Thompson (USA)
Dr. F. A. Vening Meinesz (Holland)

(8) *Financial statement for the Union from January 1, 1939, to December 31, 1945*—After discussion on (1) the recovery of income tax on Union investments, (2) the need for adoption by all constituent Associations of a uniform pattern for presentation of accounts, and (3) the advantage of each account showing clearly the total assets at the beginning and end of the period, the Assembly agreed on Resolution 14.

Resolution 14: To adopt the financial statement and accounts as presented.

(9) *Allocation of funds to the Associations of the Union*—Resolutions 15, 16, and 17 were adopted as follows:

Resolution 15: That no general allocations be made immediately to all Associations; but that allocations may be made to individual Associations as requested.

Resolution 16: After the 1946 subscriptions have been received, a general distribution of allocations should be made, according to the percentage basis defined on page 44 of the Washington Report of the Union, namely:

Association	Per cent
Geodesy	44.0
Seismology	13.0
Meteorology	8.6
Terrestrial Magnetism and Electricity	8.6
Physical Oceanography	8.6
Scientific Hydrology	8.6
Vulcanology	8.6

Resolution 17: That the Union's sub-account in the United States of America be held in cash in the expectation that it may be drawn on in the near future.

(10) *Resolutions of the Washington Assembly*—As the recent war had precluded distribution of the Resolutions passed by the Washington Assembly in September 1939, the Assembly agreed on Resolution 18:

Resolution 18: That the Washington (1939) Resolutions should not be distributed, but should be brought up for reconsideration at the next General Assembly.

(11) *Revised Statutes and Bylaws*—The draft of revised Statutes and Bylaws, prepared by Brigadier Winterbotham in accordance with the instruction of the Executive Committee at its Oxford (1945) meeting was

discussed, first in full Assembly as regards those articles involving new principles in the machinery of administration and finance, second by a special Statute Committee* as regards details and wording, and finally in full Assembly when the complete draft as modified was read article by article and discussed and agreed upon. Dr. Tardi and Col. Laclavère were asked to prepare an accurate French text and Resolutions 19 and 20 were adopted.

Resolution 19: That copies of both French and English texts of the Statutes and Bylaws be distributed as soon as practicable to all delegates present at this Cambridge Assembly so that they might have opportunity for comment before printing and circulation to all adhering organizations and countries. Points of doubt should be decided by the Chairman (Dr. Nörlund) and the General Secretary.

Resolution 20: That the new Statutes and Bylaws be then distributed to all adhering countries. If before January 1, 1947, they are not rejected by more than one-third of the adhering countries or organizations, which have duly paid their proper subscriptions for 1946, the new Statutes and Bylaws will be considered as finally adopted from that date.

(12) *Effect on the activities of the Union of the decision of the International Meteorological Organization (IMO) to dispense with some of its Commissions*—As a result of the recent decision of IMO to dissolve some of its technical Commissions whose activities appeared to overlap those of the Associations or Committees of IUGG—for example, IMO's Commission on Terrestrial Magnetism and Atmospheric Electricity—Resolutions 21 and 22 were adopted.

Resolution 21: That the Union welcomes any increased scope for international scientific collaboration by its Associations, Commissions, and Committees.

Resolution 22: That cooperation between IUGG and IMO will insure continuation of the present support of the various Government Meteorological Services in arranging collaborative activities to the mutual interest and benefit of the Union and IMO.

(13) *Election of officers of the Union*—Resolutions 23, 24, and 25 were unanimously adopted.

Resolution 23: To confirm the election of Professor B. Helland-Hansen as President of the Union and Dr. J. M. Stagg as General Secretary of the Union.

*Nörlund (Chairman), Laclavère, Lambert, Proudman, Stagg, Tardi, and Vening Meinesz.

Resolution 24: That Brigadier Winterbotham be elected first Vice-President to act as Emergency President until the end of 1946, or until such time as Professor Helland-Hansen has recovered from his present illness.

Resolution 25: That Dr. N. E. Nörlund be elected second Vice-President.

(14) *Publication of a report on the Proceedings of the Executive Committee at its Meeting in Oxford, December 1945, and of the Extraordinary Assembly in Cambridge, July-August 1946*—The Assembly agreed on Resolution 26.

Resolution 26: That after January 1, 1947, a Union Report Volume should be printed in the series of General Assembly Reports. This volume should contain:

(*a*) The Report on the meeting of the Executive Committee at Oxford in December 1945, as adopted at this (Cambridge) Assembly.

(*b*) A report on the Cambridge Extraordinary Assembly 1946.

(*c*) The Accounts of the Union and its Associations up to December 31, 1945, as adopted by the Cambridge Assembly.

(*d*) The new Statutes and Bylaws, French and English texts.

(15) *Names of Members of Council of Union*—In order to complete the Council of the Union as defined in the new Statutes, the Assembly agreed on Resolution 27.

Resolution 27: That in due time the General Secretary should invite National Committees (or adhering organizations) to nominate their delegates to the Council of the Union.

(16) *Union representation at the General Assembly of the Pan American Institute of History and Geography in Caracas, Venezuela*—The Assembly unanimously decided that Professor Vening Meinesz should represent the Union and agreed on Resolution 28.

Resolution 28: That Dr. Fleming (USA) be authorized to advance up to \$800 from the Union's sub-account in Washington to cover the traveling expenses of Professor Vening Meinesz while on Union business as the representative of the Union to the Caracas Assembly.

(17) *Spare copies of Union Reports for the first six General Assemblies*—The stock of copies of Reports of the earlier General Assemblies of the Union up to and including the Edinburgh Assembly Report (1936) was reported by the General Secretary to be exhausted. Copies that may be spared will be welcomed by the General Secretary to meet needs of new adhering countries and other bodies wishing to complete their sets.

(18) *Request by India to renew its membership in the Union*—The delegate from India reported that his country was now prepared to rejoin the Union on a two-unit basis of subscription. Resolution 29 was unanimously adopted.

RESOLUTION 29: To welcome India as a member of the Union on a two-unit basis of subscription as a provisional measure pending the adoption of the new regulations in the Union's Statutes on the subject.

(19) *Time and place of the next Ordinary General Assembly*—Because of probable difficulties of travel, exchange, and accommodation still in 1947 and which might be eased by 1948, Resolution 30 was adopted.

RESOLUTION 30: To defer the next Ordinary General Assembly (to be held in Norway) until 1948.

Professor Solberg said the Norway Assembly would probably be held during September 5-15, 1948.

At the concluding meeting the Chairman, Dr. Nörlund, addressed the delegates as follows:

"Gentlemen, we have now reached the end of our work. The series of meetings we have had have been most useful. We have framed many important resolutions and have agreed upon a new set of Statutes and Bylaws different in many important respects from the old ones. My best thanks are due to you for the work you have done during these meetings and for the good will you have shown.

"On your behalf I wish to thank our English friends and the College Authorities for inviting us to Cambridge; it has been to all of us a very great pleasure to be allowed to live in these beautiful old buildings. Our thanks also to the University of Cambridge for the privilege of holding our meetings in the School of Arts.

"Our very sincere thanks go to Dr. Stonely for all the arrangements he had made to make our stay in Cambridge enjoyable and lastly to the General Secretary for the excellent work he has done, both day and night, to make our meeting a success."

KEW OBSERVATORY,
Richmond, Surrey, England

NOTES

(See also page 579)

44. *Activities of Magnetic Section of the Zi-ka-wei Observatory at Zô-sè during the war*—The JOURNAL is indebted to Father M. Burgaud, S.J., for the following notes on the magnetic work of the Zi-ka-wei Observatory during the war.

The magnetic station was in full operation at the beginning of 1945 and the magnetograms from 1938 to April, 1945, are available. Difficulties because of the war increased daily. Owing to lack of oil for the engine, the use of electricity had to be reduced and beginning with January 1942, registration during only a few seconds every five minutes was obtained. In April 1943, it was possible to erect a gas generator and, using charcoal, registration was resumed at the speed of one point every 1½ minutes.

In April 1945, the Japanese ordered the evacuation of the Zô-sè hill. Caves had to be prepared for the battle of Shanghai. All the property was removed, storage-batteries dismounted, and the instruments were packed and transported to the Zi-ka-wei Observatory. The magnetic pavilions were occupied for a few days but no special damage was done. Magnetic observations and registration may be resumed provided a new mark is erected and new storage-batteries are procured.

The *Magnetic Bulletin* for 1939-1940 has been published and that for 1941-1942 is ready for the printer.

The Observatory suffered grievous loss in the deaths of Brother Agrunagalde, Engineer at Zô-sè, who had served the Observatory for 42 years, and of Mr. Lou-zu-tsen, Observer, who had served more than 35 years.

45. *Adolf Schmidt Observatory, Niemegk*—We are glad to learn that, after recovering from some damage incident to the war, the Adolf Schmidt Observatory at Niemegk is now in full operation. Professor Dr. R. Bock is now Director of the Geophysical Institute at Potsdam.

46. *Honolulu and College Magnetic Observatories*—The construction of the new Honolulu Magnetic Observatory of the United States Coast and Geodetic Survey [see Terr. Mag., **51**, 305 (1946)] has been completed.

The temporary magnetic observatory at College, near Fairbanks, Alaska, has been transferred, as of July 1, 1946, by the Department of Terrestrial Magnetism, Carnegie Institution of Washington, to the United States Coast and Geodetic Survey. The latter organization will operate it until the permanent observatory can be built. At present, construction is delayed by the need for putting all available building materials into housing. Ernest N. Wolff is in charge of the temporary observatory. [See Terr. Mag., **51**, 410 and 462 (1946)].

SUMMARY* OF THE YEAR'S WORK, TO JUNE 30, 1946, DEPARTMENT OF TERRESTRIAL MAGNETISM, CARNEGIE INSTITUTION OF WASHINGTON

By J. A. Fleming

The surrender of Germany in 1945 and of Japan early in the report-year (July 1, 1945, to June 30, 1946) brought to an end the long struggle since 1939, which has diverted almost all scientific investigators and organizations into paths bearing on the grim business of war. This Department's personnel and program, as briefly summarized below, have assisted the Government of the United States by taking over the development of many problems whose solutions have involved fields of its research and the worldwide data it has acquired since 1904. Happily most of the developments for defense have involved the results not only of old lines of approach to theoretical and experimental studies, but also of new lines in the Department's fields of research. Naturally the work required to complete contractural commitments—some undertaken only a few months before cessation of hostilities—with various war agencies, although in large measure done before June 30, 1946, will make some demands on administrative resources and scientific personnel of the Department for the remaining months of the calendar year 1946. It is also inevitable that more time will be needed for full consideration and decision regarding the reconversion from wartime to a normal peacetime program of research; memoranda toward solution of this problem have been under way since November 1945. The long period of considerable interruption in the Department's normal program furnishes opportunity to assess the desirability of continuing or abandoning certain activities maintained during the years before 1942 and of pursuing new objectives suggested by an examination of the status of science at the end of the war.

All members of the scientific staff were requested, therefore, to prepare memoranda on background of investigations completed or in progress, interrelations of programs of the sections and of those of other research organizations, and recommendations for future studies, facilities, and extent of personnel. Significant and thoughtful constructive and critical statements on reorganization of activities and related research were submitted in the latter part of 1945 and were thoroughly discussed in several staff-conferences. The subjects so considered were as follows: (*a*) Geomagnetism; (*b*) geoelectricity; (*c*) ionosphere; (*d*) laboratory and nuclear physics; (*e*) automatic calculation by machine in geophysical analyses and reductions. Brief extracts only from each of these statements are included under the appropriate items in the review of the year's work below. The

*For further details see Carnegie Inst. Washington, Year Book 45, 37-89 (1946).

many valuable suggestions of these complete and voluminous memoranda must be carefully considered before decision as to the extent to which, in the coming years, programs may be profitably pursued, taking account of available resources of personnel, equipment and funds, and possibility of exchange of scholars and of cooperation with other organizations active in the various fields.

Professor Sydney Chapman (Queen's College, Oxford), long expert counselor and contributor in the Department's operations and a pre-eminent world authority in geophysical research, who reviewed a complete file of the memoranda, comments as follows (January 1946):

> I found the file extremely interesting, full of good ideas and plans, and showing clearly what an able, alert, and well-assorted staff DTM has gathered together. . . .
>
> As regards nuclear and biophysics and DTM, the former is now "well dug in" and has a highly successful record in the Department. There is obviously a great field of highly valuable work in front of this Section; but there is a danger of this work gradually ousting the geophysical side. That, I think, would be lamentable, because the nuclear and biophysics is in no danger of neglect from universities and their research institutes, but the geophysical side of DTM needs greater resources and longer continuance of a stable policy than most universities could or would devote to such a subject; if CIW allowed this work to languish, a situation (as regards geomagnetic and associated research) that DTM has largely rescued from chaos and neglect would slump badly once more, whereas what is needed is a big new advance. The field of work is one that demands a considerable group of research teams led by men of first-class scientific and technical gifts, whose problems would fully stretch their powers. I like the full-blooded defense of this field in the majority of the proposals—I think it thoroughly justified; in fact, the papers in many of the proposals seem to me to outline an inspiring program of technical studies so closely agreeing, except in relative detail or omission here and there, with what I would have proposed, that I feel it unnecessary to add anything to it in such a general letter as this.
>
> There is, however, one considerable proposal in this field that I would like to make, namely, that DTM should prepare a draft plan (or perhaps more than one, as alternatives) of the organization that would be needed to put the world magnetic survey (mainly by air, and with its due complement of magnetic observatories) on a reasonably satisfactory and permanent footing. DTM is, I think, the organization best fitted by its own varied experience and knowledge to do this, though other candidates for the job might be the Coast and Geodetic Survey or our British Meteorological Office, whose comments on a DTM plan should in any case be very helpful. It seems to me clear that the world, for civil aviation and shipping, should have this job of magnetic survey done properly and regularly, and probably some UN organization (perhaps under UNESCO) is the only means of ensuring that. To bring the matter effectively before UN it is necessary to have a draft plan and tentative budget such as I suggest DTM should prepare; but I think DTM and CIW should not only make the plan, but also collect a committee of men with those talents and experience—in politics, government, and diplomacy—needed to bring the plan effectively before UN so that the plan should be likely to be adopted and put into execution. That would indeed be a grand achievement, and should result in a lightening of some of the burdens that DTM has perforce undertaken in the past—land and ocean magnetic surveys and observatory work—freeing energies for work in other directions. Certainly such a UN organization if set up would not leave DTM free from a job; the continued existence of a "free" research institution alongside

the international organization with its fixed tasks would be of great importance in providing independent critical assessment of the organization's work, and continual aid by the development of improved methods and instruments. And in any case pure geomagnetic research (in its broadest sense, as outlined in three of the proposals above referred to) would remain the field mainly of DTM and individual workers elsewhere, as now.

Geomagnetic investigations—Isoporic charts based on secular-change results at about 2000 stations were completed for epochs 1912.5, 1922.5, 1932.5, and 1942.5 for seven geomagnetic elements at ground level and for three elements throughout the atmosphere up to 5000 km. Included also were charts for the potential and vertical gradients of secular change at ground level.

Main-field isomagnetic world charts for declination (D), horizontal intensity (H), and vertical intensity (Z) based on results at about 10,000 stations since 1905, in 17 sections each, were completed for epoch 1945.0. Corresponding charts for the northward (X), eastward (Y), and total (F) components of intensity and for inclination (I) are roughed out preparatory to final inking.

Spherical harmonic analyses of the secular-change charts at four epochs were completed. It is inferred that secular change is likely to originate mainly in the mantle of the Earth in the presence of a region of extremely high electric conductivity. Spherical harmonic analyses of the main-field charts and of various geomagnetic variations are under way.

Attention has been given to the problem of magnetic surveys by air, in which it is expected that sufficient accuracy may be attained to make the data important for scientific investigation of such problems in geomagnetism as the separation of the internal and external fields of the Earth and the determination of the existence or nonexistence of the so-called nonpotential portion of the field. Though it cannot be expected that aerial observations will be as precise as ground observations, the superior coverage obtained from the air will make data so obtained more significant for analytical purposes than the present ground observations. Observing at isolated points on the Earth's surface, one is continually confronted with the "sampling problem," that is, whether or not the data obtained from a given region adequately represent the magnetic field over that region; also the ground observer is often unable to conduct observations in certain places. These conditions are present particularly over oceanic and polar regions. Isomagnetic charts based upon surface observations must always be limited, so far as faithful depiction of the field is concerned, because of the impracticability of obtaining observations at an infinite number of stations and of deductions for both the regular and irregular changes in the field.

Design and fabrication of test equipment for measurement of the geomagnetic field on an airplane, were completed. Present plans call for con-

tinuation of this work at the Department in cooperation with the armed forces on a noncontractual basis.

This development focuses attention on new ways of interpreting magnetic observations in connection with geological structure through aerial observation over regions of geomagnetic anomaly. The success of the magnetic airborne detector during the war and its release by the armed forces for research purposes afford a means of rapid and extensive magnetic surveying. The present form of this detector is capable of measuring only the total component of magnetic force, and it does not appear likely that any adaptation will permit measurement of vertical intensity or any other vectorial component of the force with any comparable degree of precision. Theoretically, no interpretation of total-force measurements is possible unless the direction of the force is also given; if the anomalies being measured are small with respect to the normal magnetic field of the Earth, however, a satisfactory approximation can be made in that the total magnetic field resolves the field of the anomaly into the component of the anomalous field which is parallel to the total-force vector, and this is the component that the detector measures. The direction of the normal field may be assumed constant over the area under investigation. If the field of the anomaly is only 100 gammas, the error introduced by this approximates to only one part in 250,000 in middle latitudes. Thus, the observed anomaly may be regarded as a vector-field in the direction of the total magnetic vector and as such is analytic. By the method of harmonic analysis, this vector-field is readily separable into its components in the vertical direction and in the horizontal direction toward magnetic north. Methods for handling data of this sort were developed.

Investigations have been conducted to improve the reliability of prediction of magnetic storms on the basis of their recurrence-tendencies, employing the principle of multiple correlation, a method which has recently been generalized by the work of Wiener. Sufficient improvement in results is obtained to make the method worth while.

Among the suggestions for geomagnetism may be noted the following: "Geomagnetic researches, including associated researches in cosmic rays and earth-currents, conform to the indicated purpose of the Department." The main problems of geomagnetism "are as follows: (1) Main field—(*a*) cause, origin, and maintenance, (*b*) properties of magnetic field of large bodies, (*c*) effect of main field on ionosphere; (2) secular variation—(*a*) cause, origin, and maintenance, (*b*) secular variation in past history of Earth, (*c*) relation to main field; (3) magnetic storms—(*a*) mechanism of magnetic storms, (*b*) electric current-systems responsible, (*c*) solar causes of magnetic storms, (*d*) prediction of magnetic storms, (*e*) relations to aurora, cosmic rays, and ionosphere; (4) solar and lunar daily variations—(*a*) relation to ultraviolet radiation of Sun, (*b*) electric conductivity of atmospheric region in which electric currents responsible flow, (*c*) relation to ionospheric

phenomena; (5) short-period geomagnetic fluctuations—(*a*) mechanism responsible, (*b*) relation to solar and allied phenomena; (6) currents induced in Earth by geomagnetic variations—(*a*) morphology of earth-currents, (*b*) inferences respecting Earth's interior, (*c*) relation to magnetic variations. The previous policy of emphasis upon observational and descriptive aspects of geomagnetism should now be reorientated toward greatly increased emphasis upon interpretations of material on hand. In these researches it is now possible to make use of automatic machines such as those of the International Business Machines Corporation for simple processes, and the more erudite devices for more difficult analytical problems are highly recommended to expedite all Department work of this type."

Cosmic relations—Provision for the maintenance and operation of cosmic-ray meters at five widely distributed locations, as noted in last year's report, was continued. Delay in reconversion to a peacetime program prevented any statistical investigations of available cosmic-ray data. The Institution's Committee on Coordination of Cosmic-Ray Investigations was disbanded June 30, 1946, and its work was transferred to the Department (see pp. 529-536).

The Department continued to act until June 30, 1946, as a clearing house for sunspot-data obtained by many observers of the American Association of Variable Star Observers and to receive and compile indices of geomagnetic activity from magnetic observatories. It is hoped that these responsibilities may once more be assumed by the International Unions of Astronomy and of Geodesy and Geophysics.

Terrestrial electricity—A reconnaissance study was made of lightning and associated electric phenomena at the Parícutin Volcano in Mexico to determine whether electrical studies under the unique conditions there would advance understanding of generation of electricity in thunderstorms. It was found that changes in the electric field associated with the volcano-cloud were much smaller than those in thunder storms.

Continuing tests and discussion on data regarding pollution of the Earth's lower atmosphere demonstrated that pollution is gradually accumulating over the ocean near industrial land areas, near principal ocean trade-routes, and also over the more isolated regions of the ocean; this accumulation has increased pollution 100 per cent or more in 15 years and raises a question as to increase in the amount of foreign gases in the air.

Study on the rate of atmospheric ionization revealed (*a*) diminution when the soil is wet as compared with that when it is dry, and (*b*) definite annual and diurnal variations.

"In the future investigations of atmospheric electricity at the Department it is recommended that attention be given chiefly to problems which involve much less in the way of amassing data and burdensome statistical analyses than has been the case in the past.

"Investigations of this character which are deemed most appropriate

and important fall in the three following categories: (*a*) Electrical phenomena and properties of the higher troposphere and of the stratosphere; (*b*) testing specific hypotheses regarding the maintenance of the Earth's negative charge; (*c*) testing specific hypotheses regarding the generation of the electricity in storms."

Ionosphere.—By means of a new technique for recording phenomena in the upper layers of the Earth's atmosphere (the ionosphere), it was found, for the first time, that during magnetic storms—intervals when the ionosphere undergoes marked fluctuations which result in the fading or even the disappearance of radio signals—rapidly moving clouds of charged, or ionized, matter rush to the ionosphere, moving in from long to short range and out again at intervals of a few minutes. The clouds are of fundamental significance in their influence on radio transmission, and travel at a speed of about a mile per second. The new photographic panoramic ionospheric recorders developed at the Kensington Ionospheric Laboratory permit obtaining individual photographs of ionospheric activity at short intervals of 5 to 30 seconds; thus it is now possible by projection of the film-records as a motion picture to have visual presentation of the results, making for easier interpretation and study and broad applications in research and education.

A review of the relation of ionospheric research to the purpose of the Department, of the results already accomplished, and of the present status of the theoretical and experimental developments readily reveals many problems remaining to be solved with particular reference to fundamental progress within the scope of the Department's facilities. These problems may be listed in four general categories, namely, (1) continuous recording and observation, (2) fundamental analyses, (3) basic experiments, (4) specific engineering and prediction services.

Programs of particular interest to the Department in future lie particularly in (2) and (3), and are suggested "with the following criteria in view: (*a*) They must be of fundamental importance to the science as a whole; (*b*) they should endeavor to avoid duplication of the work of others; (*c*) they should supplement the work of others in the Department; (*d*) they must be within the limit of material resources which can reasonably be made available; (*e*) they should fit other geophysical programs of the Department to permit the maximum of organized research on geophysical problems of general interest without completely subordinating the importance of individual researches; (*f*) they should visualize definite answers within reasonable time-limits, with at least a sprinkling of experiments which lead to a definite conclusion in not more than a few months; (*g*) they should be sufficiently flexible to provide facilities to follow through quickly on a new or spectacular discovery."

The suggested objectives are "fundamental, experimental, analytical, and theoretical investigations of: (*a*) The ionized regions of the upper

atmosphere and of the space beyond; (*b*) the sources of this ionization; (*c*) the effects of this ionization; (*d*) related geophysical or extraterrestrial processes whose investigation is made possible by the presence of these ionized regions, or by the methods and techniques developed for their investigation; (*e*) the related morphology of the atmosphere."

Nuclear physics—The 1,000,000-volt electrostatic generator was reconditioned. Preliminary investigations were made on the angular distribution of the protons from the reaction $O^{16}(d,p)$. Progress is being made on revision of the electrostatic pressure-generator and tube to improve performance and reliability.

The 60-inch cyclotron was operated satisfactorily throughout the year, especially for bombardments for application to biophysical research. There was also produced one large sample of beryllium as a by-product providing a source of Be^{10}, the radioactivity of which presents problems as to the theory of the structure of light nuclei and that of beta decay.

The outstanding comment in the memorandum on the laboratory program is recognition of the scientific importance of past and current laboratory progress in nuclear physics and biophysics with the reservation that a more general program in laboratory physics is a vital part of any over-all program. The relations of such a program to the highly developed special interests "may roughly be classified as (*a*) systematics and relations of terrestrial magnetism and electricity, (*b*) experimental geophysics (including ionosphere), (*c*) laboratory physics. . . . The most outstanding and immediate need is for a Section on Theoretical Physics."

Observatory- and field-work—The complete geomagnetic, atmospheric-electric, ionospheric, seismic, and meteorological programs were maintained at the Watheroo, Huancayo, and College magnetic observatories. Special studies relating to geomagnetic, atmospheric-electric, and ionospheric problems were made by the staffs at each observatory. The atmospheric-electric program in cooperation with the United States Coast and Geodetic Survey at its Tucson Magnetic Observatory was continued. The Department cooperated, through loan of instruments and otherwise, with eight observatories abroad.

Maintenance of International Magnetic Standards at the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey was effected through the Division of Geomagnetism and Seismology of the Survey.

Though no field-work other than that at the observatories could be undertaken, it was possible to assist various governments, through loans of magnetic instruments, in undertaking new magnetic surveys and obtaining repeat-observations at established stations.

In view of the desideratum that the Department concentrate increasingly on theoretical matters and discussions of its accumulated geophysical

data, considerable progress was made toward the transfer of the Watheroo and Huancayo magnetic observatories to agencies capable of maintaining the programs at the high standards set since they were established in 1919 and 1922. To this end preliminary arrangements have already been effected as regards the transfer of site, buildings, and equipment at Watheroo to the technical and administrative control and operation of the Australian Bureau of Mineral Resources, Geology, and Geophysics. That Bureau has now been established on a permanent basis by the Australian government and has been charged with the responsibility for the magnetic survey of Australia. The Bureau has already taken over the Toolangi Observatory, near Melbourne. It will be recalled that the Department has cooperated for many years with the Aerial, Geological, and Geophysical Survey, now absorbed in the Bureau, in magnetic observations in Australia. It is contemplated that the transfer will be concluded on July 1, 1947.

Miscellaneous—One suggestion, many times emphasized in the memoranda submitted on organization of our activities, relates to arrangements for exchange of scholars and graduate students qualified in geophysics. This has been carried on for many years by extending the privilege to such men of being guest-investigators, fellows, and research associates of the Department at Washington. During the report-year arrangements were concluded with the Institut de Physique du Globe of France, the University College of Dublin, Ireland, the Academia Sinica of China, and the Research Council of India for their representation by graduate students who will pursue geophysical research and training at the Department during the coming report-year. The Department, through its already established widespread connections and prestige in foreign lands resulting from its geophysical activities, is well suited for such international cooperation.

The continued services of two retired members of the staff, J. W. Green and W. F. Wallis, have been most useful in the emergency.

Henry Freeborn Johnston was retired June 30, 1946, because of ill health. He was active in the Department for over thirty years and took part in practically every branch of our program including the survey on land and sea and the work at observatories and at Washington. He did arduous field-work in South America and Africa and was for nearly six years Observer-in-Charge of the Watheroo Magnetic Observatory. From 1931 to 1946 he was Chief of the Section of Observatory-Work. His record is one of devotion and efficiency during his many years of scientific activity in the Department.

Fleming, who joined the staff as Chief Magnetician on May 1, 1904, was retired as Director on June 30, 1946. Tuve, a member of the staff since 1925, was appointed Director effective from July 1, 1946—a most suitable recognition of his proved outstanding ability as a scholarly investigator and of his splendid record in national-defense problems.

Review of war applications, 1940-46—It was possible to complete by or before June 30, 1946, all but three of the contracts undertaken by the Institution at the Department. These were (1) with the Signal Corps of the Army for establishing and operating ionospheric stations and developing apparatus, (2) with the Bureau of Ships of the Navy for compass improvements, and (3) with the United States Maritime Commission for work on compasses; all these will terminate within two to six months.

During the report-year the total number of progress-reports and final statements on results obtained under nonprofit cost contracts since 1940 was nearly 150. The contractual obligations, though not so heavy as in the preceding year, still took at least 80 per cent of the services of the available full-time and part-time regular staff of 64 in Washington and at the observatories. One hundred and sixty-four temporary employees (including physicists, engineers, mathematicians, computers, tabulating-machine operators, machinists, clerks, and guards) were necessary, and the total peak number of all persons engaged by the Department during the year was thus 228. Besides these, eleven of the regular and two of the temporary personnel continued on leave of absence either in the armed services or in governmental war agencies for part or all of the report-year; of these, four returned to duty at the Department in January, two in February, and two in May. In spite of the unrest of temporary personnel, hired for work on commitments to various war agencies, and their desire to secure permanent employment as soon as possible, these obligations have been essentially completed during the report-year. Many of the temporary personnel were again made available by various universities and individual organizations through generous granting of leaves of absence.

In view of the declassification of the developments at the Department on military problems, largely concerned with applications of geophysics, it is now appropriate to give a brief summary of operations for the years 1940 to 1946.

Most of the work at the Department was done under nonprofit, nonoverhead, cost contracts of the Institution with the Office of Scientific Research and Development and its National Defense Research Committee, various bureaus and laboratories of the departments of War, Navy, Interior, and Agriculture, the Maritime Commission, and National Institute of Health, and, more recently, the Office of Research and Invention of the Navy Department. Through June 30, 1946 (at which time all contracts except three had been completed), the total of costs was $2,359,895.45. In addition, the Institution made available at the Department during 1940 to 1946, and without charge, all services of the regular scientific and administrative staff and use of all buildings and equipment there; a very conservative estimate of these contributions is well over $500,000. Besides these, again at its own expense, the Institution built an addition to the

instrument-shop of its main laboratory and made many structural changes in its several buildings at the Department—all necessary because of contractual responsibilities.

The outstanding accomplishments are:

Navy Bureau of Ordnance: Compilation and preparation of world isomagnetic charts of seven components of the Earth's magnetic field; establishment of the Kensington Magnetic Laboratory and experimental studies and tests of magnetic mines and torpedoes; experimental magnetic and radio field-research at the College Observatory, Alaska; various magnetic investigations at Washington and in the field. The earliest of these contracts, some of which were continuations of earlier contracts with the National Defense Research Committee, began in August 1940.

Navy Bureau of Ships: Work on improvement of ship's compasses from April 1945.

Navy Bureau of Supplies and Accounts: One contract called for investigations of the ionosphere, wave-propagation, geophysics, and solar and cosmic relations at Washington, at College, and at many cooperating astronomical observatories, and was effective from July 1942 to June 1946; another concerned detection appliances by means of marine and land electric currents, and was completed during March 1942 to December 1943; a third contract concerned isomagnetic charts during February to June 1942, and was superseded by a contract with the Bureau of Ordnance (see above).

Navy Bureau of Aeronautics: A contract concerning methods of aircraft navigation was completed during the year ending in June 1946.

Navy Medical Center: Special radioactive isotopes by cyclotron bombardments, for biophysical investigations, were supplied from June 1944 to June 1946.

Naval Research Laboratory: An especially valuable research on separation of uranium isotopes was completed during October 1940 to June 1941, in anticipation of the atomic-bomb development. During October 1944 to June 1945, special studies, design, and construction of atmospheric-electric recording equipment for use on airplanes and dirigibles were carried out.

Army Air Forces: Research and tests on applied methods of magnetic navigation for aircraft were completed during the year ended May 1946.

Army Engineer Board: The successful design and construction of several magnetic devices for detecting surface and marine mines were accomplished during November 1944 to July 1946, in continuation of a contract with the Office of Scientific Research and Development beginning in August 1941. Altigraphs were designed, constructed, and tested under a second contract during July 1945 to May 1946.

Army Signal Corps: The establishment and operation of widely scattered stations in the Atlantic and Pacific areas and development, construc-

tion, and tests of special recording and manual equipment for observations and discussions of ionospheric phenomena and their effects on radio-wave propagation have constituted a major war activity. This work was set up originally under a contract with the Office of Scientific Research and Development in July 1942, and was transferred to the Signal Corps auspices from February 1943; the present contract will terminate in December 1946, by which time authorized transfer of the ionospheric stations to the new Central Radio Propagation Laboratory will have been completed.

The Ionospheric Section, in the Allied program for improved knowledge of radio-wave-propagation conditions, installed, operated, and/or equipped fifteen ionospheric stations. These included: (*a*) An expanded schedule at the CIW Huancayo, Watheroo, and College magnetic observatories; (*b*) new stations with civilian personnel at Clyde (Baffin Island), Maui (Territory of Hawaii), Trinidad (British West Indies), Reykjavik (Iceland), Christmas Island (South Pacific), and Adak (Aleutian Islands, Alaska); (*c*) apparatus for new stations and training of civilian personnel for Leyte, Guam, Okinawa, Loshan (China), and one proposed (China—equipment now stored in Shanghai); (*d*) apparatus for St. Johns (Newfoundland) under Canadian auspices. A coordinated solar observing program was organized and maintained providing a basis for forecasting of ionospheric disturbances. A developmental program was conducted at the Kensington (Maryland) Ionospheric Laboratory to provide a new technique for ionospheric investigations which has broad applications in research and education.

Practically all the many classified reports on this activity under contracts with the Army, Navy, and Office of Scientific Research and Development, originally distributed to a limited list of authorized and interested parties, are now declassified. Already revision of the material where necessary is under way to prepare it in form suitable for publication in recognized technical journals.

The program set up by the Wave Propagation Committee has demonstrated in its results the urgent need of continuation in the postwar future in the general national interest, and it is apparent that continued obtaining of data from widespread stations is essential to military, commercial, and research postwar responsibilities and activities. Certainly the stations in Hawaii, in Alaska, on Christmas Island, on Trinidad, in the Aleutians, and in the Philippines should be placed on a permanent postwar basis and the ionospheric programs at Watheroo and Huancayo should be maintained for some years.

Army Service Forces (*Supply Division, Camp Detrick*): Radioactive materials, produced by the cyclotron, were supplied in January 1945.

Bureau of Plant Industry (*Agriculture*): During January and August 1945, special radioactive isotopes were supplied.

Geological Survey (Interior): During June to August 1946, an earth-current recorder was supplied, installed, and set in operation at Umnak Island, Alaska.

National Institute of Health: During August 1944 to June 1946, considerable quantities of radioactive elements and compounds, for biophysical research, were supplied.

Maritime Commission: The study of compass-behavior and improved compass-design are the subjects of a year's contract, to terminate in August 1946.

Office of Scientific Research and Development (including National Defense Research Committee): Some of the most important contributions by the Department were completed on contracts with the Office of Scientific Research and Development and the National Defense Research Committee; others initiated by that Office and that Committee were so important as to be transferred later to military agencies for further development, as indicated above.

Outstanding among these were the development and tests proving practical feasibility of the radio proximity fuze, which were transferred by March 1944, with 100 staff members and equipment, for final arrangement of mass-production design and manufacturing to the Applied Physics Laboratory of Johns Hopkins University, especially inaugurated for that purpose. The development of the fuze began in August 1940, and was completed at the Department in March 1944. For some months prior to April 1943, the new Johns Hopkins group maintained operations at the Department pending completion of reconstruction of buildings to house it at Silver Spring.

Another development of prime importance was begun in April 1941 and completed in May 1945, on development of the odograph—an automatic route-drawing device, true in direction and scale, for use in tanks and on land, air, and ocean vehicles of all kinds—and the pedograph (a light-weight version of the odograph for use by individual soldiers), which involved extensive study of compensation and design of compasses and electronic circuits.

The development of magnetic mines was carried on for the Office of Scientific Research and Development during three years ended in August 1944; this work and that on the odograph were later made parts of contracts with the Army Engineer Board.

As above indicated, the ionospheric investigations in Alaska, subsequent to the installations and the first year of operation at College, on funds provided by the Institution, were supported by contracts with the Office of Scientific Research and Development during March 1941 to June 1943, when transfer to Navy auspices was made. That Office also supported by two other contracts the original work done during August 1943 to June 1944 on the direction-finder program at College, and during July 1942 to No-

vember 1943 on aspects of solar and geomagnetic investigations at Washington.

An important contribution was that relating to fission of uranium during September 1941 to September 1943.

Office of Research and Invention: The Department has kept closely in touch with the recently formed Office of Research and Invention of the Navy Department. It has attended many conferences of that Office and has furnished advice on many geophysical subjects within the province of the Department's activities.

All the above contractual obligations, though interrupting the regular scientific program, have yielded by-products and improved techniques applicable not only to geomagnetic surveys and experiments, but also for mass reductions, analyses, and correlations by machine methods. Peacetime applications of these must serve both the continuation of surface magnetic surveys and the initiation of aerial ones by various governments, as well as interpretative investigations of the vast existing stock of data, and the potentially much greater stock which may be available in the near future. It is hoped that a long period of amity and cordial relations among all nations is now on the horizon, affording firm foundation for forwarding and coordinating future large activities in Earth physics.

Carnegie Institution of Washington,
Washington 5, D. C., December 16, 1946

COMMITTEE ON COORDINATION OF COSMIC-RAY INVESTIGATIONS

By J. A. Fleming

This Committee, whose members have been W. S. Adams, J. A. Fleming, and F. E. Wright since formation by the President of the Carnegie Institution of Washington in December, 1932, to coordinate research on cosmic rays supported by the Institution, has submitted its fourteenth and final annual report* for the year ended June 30, 1946. With the retirement from active service in the Institution on or before June 30, 1946, of its three members, the Committee recommended to President Bush that, effective July 1, 1946, (1) administration of its then uncompleted activities be made the responsibility of the Department of Terrestrial Magnetism of the Institution, and (2) funds still available from past appropriations be set

*Carnegie Inst. Washington, Year Book No. 45, 91-98 (1946); for previous reports see Year Books Nos. 32 to 44. For a statement on formation, purposes, and policies of the Committee see Year Book No. 38, 335-349 (1939).

aside, in accordance with the approved projects listed below, for disbursement by that Department through its Director. The President approved these recommendations and future reports on the completion of projects sponsored by the Committee will be made in the annual reports of the Director of the Department of Terrestrial Magnetism.

As has been indicated in the annual reports* of the Committee from 1940, relatively large progress could not be made during the war years. In view of the fundamental importance of this branch of physics, this limited progress, as one would expect, has raised more questions than answers. With the cessation of hostilities and the eventual reconversion from wartime to peacetime efforts of the investigators in the field of cosmic radiation, it may well be expected that research will be vigorously resumed, particularly in the investigation of high-energy radiations to which natural cosmic radiation gives an immediate avenue of approach. Thereby we may expect to learn basic facts by which to check theories of nuclear forces and interactions between radiation and matter.

The programs, supported in whole or in part by the Committee, of groups at the Department of Terrestrial Magnetism of the Carnegie Institution, at the Bartol Research Foundation of the Franklin Institute, and at New York University, so far as emergency and reconversion conditions permitted, have gone forward during the year.

The Department of Terrestrial Magnetism continued to supervise operation of the Carnegie Institution's precision cosmic-ray meters at the following stations: Cheltenham (Maryland, United States) Magnetic Observatory of the United States Coast and Geodetic Survey, John Hershberger and William E. Wiles in charge; Huancayo (Peru) Magnetic Observatory of the Department of Terrestrial Magnetism, Carnegie Institution of Washington, P. G. Ledig in charge; National Astronomical Observatory of Mexico at Teoloyucan (D. F., Mexico), Dr. Joaquin Gallo in charge; Amberley Branch of the Christchurch (New Zealand) Magnetic Observatory of the Department of Scientific and Industrial Research, J. W. Beagley, succeeded December 1945 by V. B. Gerard, in charge; Godhavn (Greenland) Magnetic Observatory of the Danish Meteorological Institute, K. Thiesen, succeeded October 1945 by Mr. Lundbak in charge.

Because of the Department's participation in defense problems and demands incident to reconversion it was not possible to effect the scaling, reduction, and analysis of the large mass of cosmic-ray data which accumulated during the war. Considerable attention was given, however, by Mr. Scott E. Forbush and Miss E. Lange to examining methods by which the time consumed in the scaling, reduction, and analysis might be minimized. This results in a reduction of one-third in the time involved in scaling and provides the results in such form that subsequent reductions and analyses can be largely effected by using International Business Machine equipment. Thus it was possible, by June 30, 1946, to scale the accumulation of

data during five years of war from the Huancayo Magnetic Observatory. The subsequent reductions and analyses can be effected almost entirely by machine, thereby saving a great amount of arithmetical labor. It is planned to reduce and analyze similarly by machine the accumulated data from Cheltenham and Godhavn. Together with the material reduced before the war there would thus be available for analysis and publication, bi-hourly means of cosmic-ray intensity (bursts deduced and corrected to constant barometric pressure) for the following stations: Huancayo, June 1936 to June 1946; Cheltenham, March 1937 to June 1946; and Godhavn, October 1938 to June 1946. Data obtained, during April 1936 to December 1945, at Christchurch have been scaled (by personnel at Christchurch) and the daily means reduced to constant barometric pressure, although bi-hourly means have not been corrected for barometric pressure. Daily means obtained at Teoloyucan, during February 1937 to about July 1945 corrected for barometric pressure (reduced at the University of Chicago), should also be available.

Investigations and analyses of the data have been inevitably delayed pending processing accumulated records. It is expected, however, that the analyses will be much expedited by use of the International Business Machines. It is planned to extend some of the investigations, heretofore made on the basis of limited data, to include a longer series. Analyses of the world-wide effects can now be extended practically through a sunspot-cycle to determine whether there is a permanent external Earth's field which changes intensity with sunspot-cycles. Diurnal variations (solar, lunar, and sidereal) can be rapidly reexamined with the International Business Machines on the basis of much more extensive data; similarly for the seasonal changes. It is also planned to determine whether the frequency-distribution of burst-size at Huancayo (where burst-frequency is greatest) is influenced by magnetic disturbance and whether it is subject to sidereal or lunar variations. Lunar variations are of interest as a possible means of determining whether the moon has a magnetic field. With continued use of the computing facilities and sufficient assistance it may be possible early in 1947 to realize the objectives which the Committee on Coordination of Cosmic-Ray Research had in mind when the world-wide program of continuous registration was initiated.

At the Bartol Research Foundation, in continuation of the studies made possible by financial grants from the Institution before the war, Dr. T. H. Johnston reports that 40,000 cloud-chamber photographs taken with the large 24-inch cloud-chamber at the Foundation prior to 1942 were analyzed by R. P. Shutt. From these photographs it has been possible to determine the cross-sections for anomalous, non-Coulomb, single scattering of mesons by comparing the scattering in two different thicknesses of lead, a method which had been used in an earlier work published in 1942. The scattering of mesons of energies above about 500 million volts through angles ranging

from 5° to 90° was found to be predominantly anomalous and not of the type that could be described as due to the *electric* fields of the atomic nuclei. This scattering may be attributed to the strictly nuclear forces and as such would depend upon the spin of the meson.

About 75 photographs showed the simultaneous occurrence of several mesons and it was shown that many of these were associated in true meson showers. In comparing results obtained with two different thicknesses of lead above the chamber it was inferred that the probability of production of meson showers is proportional to the thicknesses up to 88 cm of lead and 60 cm of concrete. Many unusual photographs were obtained in this series displaying phenomena difficult to interpret in the light of accepted theoretical concepts.

At New York University Professor S. A. Korff reports that the program of study of Geiger counters has continued on deadtimes and resolving-times and on further developmental work on counters with special designs. Triode counters, employing grids to alter the field distribution, were built and the deadtimes of such counters have been measured. As was anticipated, the deadtimes of counters of this design are substantially less than those of the conventional variety. Further experiments in the direction of reducing operating voltages and shortening recovery times, as for example, by eccentric positioning of the central wire, are in progress. Other possible filling gases are also being studied.

The study of cosmic-ray neutrons at the University had led to the conclusion that the energy-distribution of neutrons in the free atmosphere should be determined by scattering in nitrogen. On the basis of this, an energy-distribution containing a good many neutrons of low velocity but few of thermal velocity was predicted. A balloon-flight was made in order to study this point. In this flight, a neutron-counter was sent aloft, and was equipped with two shields which during the flight alternately covered the counter and left it exposed. Thus a counting-rate curve was obtained with a single counter with two different shields as a function of elevation. The energy-distribution of the number of neutrons in the atmosphere derived from these data was found in satisfactory agreement with the theoretical predictions. The number of neutrons, as well as their energy-distribution throws some further light on the problem of the processes by which these neutrons are produced. It is believed that they are due to an interesting variety of photodisintegration of the nucleus in which one or more nuclear particles are ejected by the high-energy photons present in the cosmic radiation. It is presently believed that, when a high-energy photon is absorbed by a nucleus, the effective "temperature" of the nucleus becomes very high, and one or more nuclear particles may be "evaporated" out. Both protons and neutrons are produced thus, and a detailed study of the process, of its dependence on altitude, and of its connection with other cosmic-ray phenomena is under way.

Advice as to prospective completion of work under way, from the other groups who have so long and ably taken part in the researches as listed in the annual reports of the Committee since 1932, is summarized below.

For the California Institute of Technology, Dr. Millikan says:

We are already started vigorously on the program of *counter-registered flights* to the top of the atmosphere in the area between Oklahoma City and Saskatoon. Such flights are exceedingly vital because it is in this latitude range that our predictions locate the incoming hydrogen rays, which is the last and most critical latitude in which our theory of the origin of cosmic rays has not yet been carefully tested. We shall need the whole of the balance now available to complete this program. The needed balloons are better than the prewar balloons, but they cost two or three times as much as the old ones. Further, we shall not start on this expedition until we have finished satisfactorily the job which we are now on, which is "improving the reliability of counters" above that of those that have been available in the past. . . . It may be necessary to postpone the flights until the summer of 1947, for the winter winds and other conditions introduce considerable hazards which are not met with in the more stable conditions in summer and fall.

For the group which was also originally at California Institute of Technology, Professor Carl E. Nielsen reports that he has been appointed to the faculty of the University of Denver and hopes soon, therefore, to do more cosmic-ray research on Mount Evans, using the cloud-chamber and magnet provided at California by the Committee. He thinks of getting more data on the mass of the meson and of studying further the relative numbers of electrons, mesons, and protons at various elevations. Dr. Nielsen further states that during the first half of 1946:

After various delays, including the interruption of Frost's work by his induction into the armed forces, an experiment was finally set up for getting the ionization-curve for slow electrons needed before the analysis of the meson-mass data obtained in 1942* can be properly concluded. . . . A somewhat novel arrangement is used involving photographing the tracks in a direction perpendicular to the magnetic field. This makes it easy to get the electrons into the cloud-chamber since they spiral around the lines of force, and it permits much more accurate measurements of momentum of slow electrons than does the conventional set-up. The few pictures already taken this way look very promising.

The study on motion of cosmic-ray particles in the Earth's magnetic field by Professor M. S. Vallarta remains at a standstill, as stated in previous reports, because of limitations imposed by the war on the use of the differential analyzer at the Massachusetts Institute of Technology, which is required in his work.

The cosmic-ray data obtained at the Teoloyucan station (elevation 2285 meters) in Mexico exhibit certain unexplained anomalous features when compared with the records of cosmic radiation at the four other stations; the data seem to disagree with the accepted hypothesis of variation with geomagnetic latitude. The Committee was happy, therefore, to

*See Carnegie Inst. Washington, Year Book 42, 62 and 68-69 (1941), 41, 102 (1940).

be advised by Professor Amadore Cobas, who has done considerable cosmic-ray research, that the Faculty of the Natural Sciences of the University of Puerto Rico would like to provide for the installation of a CIW meter at Rio Piedras. Rio Piedras is practically in the same geomagnetic latitude as Teoloyucan, but at sea-level, and records obtained there for a year or two, while the program at the Mexican station is continued, should confirm the anomaly, or, if not, should provide means of explaining it. The University's invitation was accepted and arrangements were made by transfer of a meter, not in immediate use at the University of Chicago, to Washington for minor improvements before making shipment to Puerto Rico. The personnel of the Department of Physics, of which Professor Cobas is the head, will install and operate the meter, transmit the data to Washington, and probably undertake some discussion thereof.

Plans were considered by Dr. T. H. Johnson for further use of the high-pressure cloud-chamber constructed, in part from funds of the Carnegie Institution of Washington, after his design and supervision, at the Bartol Research Foundation of the Franklin Institute. These suggestions involve the use of the chamber for special research in connection with a betatron. Since the X-rays from a betatron have sufficient energy and may produce mesons, which heretofore could only be observed infrequently in cosmic radiation, the betatron may offer a unique opportunity for studying the characteristics of mesons; use of the pressure cloud-chamber would be of great advantage as compared with the ordinary cloud-chamber in this as in the case of cosmic-ray tracks. The chance of observing meson-decay is about one thousand times greater in the high-pressure chamber than in the ordinary cloud-chamber, and this is ample justification for the proposed use of the high-pressure chamber in connection with a betatron.

In a general summary of the present status of the fields of cosmic-ray research, submitted to the Committee through President Bush, Dr. Johnson, who has so long and ably collaborated with us, believes "that a field bristling with unsolved problems now ripe for attack with good promise of successful and important results . . . cannot but enlist men to carry on a program on as large scale and at as fast a pace as would be economical." He is "impressed with certain important advantages of a research institute over a university laboratory for cosmic-ray investigations. In the first place much of the work is difficult to adjust to an academic schedule, and secondly, although the university has advantages of providing an influx of young minds and of stimulating comprehensive analyses of research results through lectures on a graduate level, yet these advantages may also be realized in a research institute if the group is of sufficient size, and if provision is made to have a rotation of outstanding theoretical physicists attached to the group at intervals on a consulting basis."

Dr. Johnson offers also the following comments:

The most promising experimental studies to be made concern the nature and energy-distribution of the primary cosmic rays and the genetics of the secondaries produced in matter by them, especially the role played by the meson. . . . Mesons were first invoked to explain nuclear forces, but almost simultaneously particles of similar properties were discovered as the main component of the cosmic radiation at sea-level. Attempts by Nordheim, Oppenheimer, Heisenberg, and others to form an over-all picture of the cosmic radiation consistent with the available experimental evidence, including the meson interpretation of nuclear forces, have come to the view that the primary cosmic rays are protons (consistent with east-west measurements in 1933-36 and the recent work of Schein, Jesse, and Wollan), and that these produce in the high atmosphere two kinds of mesons, one of short decay-period and another of longer decay-period. The former disintegrate almost at their point of production giving rise to the electrons and gamma rays of the soft component while the latter form the penetrating component observed at sea-level and below. In the absorption of mesons the electrostatic interaction between its charge and the electrons of matter leads to the normal ionization, but the "magnetic-spin" interaction seems to be important in production of bursts, especially at great depths where the average energy is higher. The theories seem to explain most of the observations, but in many points the evidence is scant, and there are many unexplained phenomena such as cloud-chamber pictures of several hundred soft electrons emitted from a single point and definitely not to be explained by the usual cascade theory. The theory is also vague in accounting for meson showers, and the presence of high-energy protons at sea-level. To tie the whole thing down will require much careful measurement. The following are needed: Statistics on the probability of decay of mesons as a function of sign of charge, remaining energy and previous history in matter; measurements on the distribution in angle of mesons scattered in matter as a function of their energy to determine the law of force between mesons and nuclei; measurements of the angles and energies of mesons produced in showers to throw light on the process of production of these particles; statistics on the frequency of meson production and decay at several altitudes and depths below sea-level to find out what kinds of rays are producing them and whether there is really more than one kind of meson; measurements of the mass and statistics regarding the distribution of masses; visualization of the previously postulated processes taking place in the gas of the high-pressure cloud-chamber; statistics on the angles and energies of electrons kicked out of atoms by mesons; more information on the energy-distribution of the primary rays of the type that can be obtained by the balloon techniques. . . . Techniques are already available for most of these studies. The large low-pressure cloud-chamber built by Carnegie funds at the Bartol Foundation should be continued in operation, and work with the new high-pressure cloud-chamber first put into operation by Shutt, de Benedetti, and Johnson in 1942 should be used in its present form, and this principle should be further developed. Other expeditions will be required for cloud-chamber studies at high altitudes and for balloon-flights in several latitudes. Underground studies should also be made with cloud-chambers and counter-tube arrangements.

The balance ($17,500) of the funds so generously allotted for the activities of the Committee and eminent cosmic-ray investigators since its formation in 1932 is sufficient to provide for the completion of data over one sunspot-cycle, as originally contemplated by the Committee, at each of the stations where CIW model-C cosmic-ray meters have been installed. The only exception is the station at Puerto Rico, where it is desired only to obtain data for one or two years to clarify apparent anomalies observed at

the station at Teoloyucan, Mexico. As regards balances for individual investigators, they are sufficient to meet needs for final expenses and reports on researches planned which have had the approval and support of the Committee for some years. These approved projects, for which progress has been reported annually, all nearing completion, are as follows:

(*a*) Cosmic-ray studies with 24-inch high-pressure cloud-chamber to obtain additional information on the character and behavior of the meson, using improved arrangements of lead absorbing and scattering plates (Dr. T. H. Johnson).

(*b*) Measurements on meson-production layer and correlation with meteorology (Dr. S. A. Korff).

(*c*) Counter-registered flights to the high atmosphere in range of latitude between Oklahoma City and Saskatoon to test earlier hypothesis* on predictions of incoming hydrogen rays—the last and most critical range of latitude in the theory of origin of cosmic rays—and improvement of reliability of counters (Dr. R. A. Millikan).

(*d*) Further cosmic-ray research and discussions of accumulated observations and photographs on Mount Evans (Dr. Carl E. Nielsen).

(*e*) Investigation of the motion of cosmic-ray particles in the magnetic field of the Earth, the theory of magnetic storms, and related problems utilizing modern automatic calculating techniques (Dr. M. S. Vallarta).

(*f*) Continuation of cosmic-ray automatic recording with CIW model-C meters in order to complete data for a period of at least one sunspot-cycle at Cheltenham (United States), Christchurch (New Zealand), Godhavn (Greenland), Huancayo (Peru), and Teoloyucan (Mexico), and of similar recording, under the skilled supervision of Professor Cobas, for one or two years at Rio Piedras (Puerto Rico), all for sound statistical treatment as regards both regular and irregular variations of cosmic radiation with short and long periods of time, with geographic distribution, and with other cosmic (especially solar) phenomena (S. E. Forbush and Miss I. Lange and cooperating organizations).

The Committee concludes this final report with grateful appreciation for the privileges it has enjoyed since 1932: the association with many eminent investigators who have always selflessly striven for progress; the cooperation of many scientific organizations which have provided without charge observing facilities and trained personnel to obtain continuous records with the CIW cosmic-ray meters; and the large financial support given by the Carnegie Corporation and the Carnegie Institution of Washington and sponsored by Presidents Merriam and Bush.

Carnegie Institution of Washington,
Washington 5, D. C., December 16, 1946

*Carnegie Inst. Washington, Year Book 43, 56-60 (1942).

AN ATTEMPT AT AN IDENTIFICATION OF THE *M*-REGIONS

By M. Waldmeier

Abstract—*M*-regions develop in the vicinity of large sunspot-groups after the disappearance of the spots and provided that no new spots are formed at the place considered. This last condition contains the explanation of the fact, that the appearance of *M*-regions is confined to times of great sunspot scarcity preceding the minima of solar activity. Further phenomena accompanying the appearance of sunspots are the prominences, which only survive in the original sunspot-region as long as no new spots are formed in it. The velocity of the P_k-radiation lies between 300 and 600 km/sec. As in the years preceding the minimum the seat of solar disturbances lies in low heliocentric latitudes, and as on the other hand the angular velocity of the prominences, whose latitude is about 10° higher than that of the spots in which they originate, practically coincides with the angular velocity of the latter, a very narrow connection in space and time between the prominences and the *M*-regions is strongly indicated. The special case of a disturbance center in high latitude has been studied in detail. The material presented goes to confirm the working hypothesis, suggested some time ago by the author [see 10 of "References" at end of paper], "that certain narrowly limited regions of the Sun's surface emit during comparatively long periods of time a corpuscular radiation. These so-called *M*-regions are always situated in the sunspot-zone, but within this only in regions devoid of spots. With the appearance of photospheric disturbances the *M*-regions disappear, possibly as a consequence of the magnetic fields accompanying the spots."

Introductory remarks—The well-known fact, that the lesser magnetic disturbances show a clear tendency to repeat themselves after a period of 27 days is well demonstrated by the day-by-day records of magnetic activity of Bartels [1]. The 27-day sequences contained therein are particularly conspicuous on the descending branch of the curve of solar activity. They point to the existence of long-lived sources of corpuscular radiation of comparatively small extension, which Bartels has named the *M*-regions of the solar surface. A comparison of his magnetic diagrams with similar diagrams constructed for sunspots and for regions of chromospheric faculae led Bartels to the negative conclusion "that no resemblance appears between the diagrams for the magnetic activity and the diagrams for the solar phenomena, even if the possibility of a general lag of several days is taken into account". As the remaining characteristics of solar activity, namely the dark H_α-filaments and the calcium flocculi, are strongly correlated with the relative sunspot-numbers, Bartels concludes "that the *M*-regions cannot be traced in the direct astrophysical observations".

Soon after the intensity of the coronal line 5303A had been introduced by the present author in 1939 as a new index of solar activity, it became apparent that the so-called *C*-regions, in which this line is particularly prominent, possessed statistical properties quite similar to those distinguishing the *M*-regions, and were therefore either closely related to, or even possibly identical with, the long sought-for sources of corpuscular

emission, a supposition which our observations tend to confirm [2, 3]. This interdependence of corpuscular emission and 5303-intensity has recently received still further confirmation through the work of other investigators [4]. However, the completed (but still unpublished) analysis of the observational material relating to the years immediately preceding the minimum (1942-44), in which a particularly strong development of M-regions should have been expected, has shown that the corpuscular radiation only partly proceeds from the C-regions, so that further sources of this radiation will have yet to be sought.

A possible connection between the corpuscular emission and stationary prominences seems to be indicated by the following facts:

(*a*) The life periods of stationary prominences are of the same order of magnitude as those of the M-regions, namely, from several months to one year.

(*b*) The correlation-coefficient between geomagnetic activity and the areas of prominence-profiles is considerably greater than for all other photospherical and chromospherical index-numbers [5].

(*c*) An inspection of Bartels' diagrams shows that the characteristic M-regions are mostly situated in such parts of the Sun's surface, as are practically free from photospheric disturbances. This is likewise true of the stationary prominences, which either appear in undisturbed regions, or when they originate in sunspot-groups, only attain their full development several months later, when the parent sunspot-group has long since disappeared [6].

(*d*) Besides the corpuscular emission P_k here considered, there is an eruptive emission P_e proceeding from violent chromospheric eruptions [7]. This emission has not yet, it is true, been observed on the Sun's surface itself. The only two solar phenomena corresponding to a flux of particles known to us at present are as follows. (1) The concluding stage of a stationary prominence, consisting in a general upward motion of the latter, the speed increasing steadily with the height above the solar surface and apparently tending to an upper value of 300 to 500 km/sec. (2) The long coronal streamers, most frequently seen on eclipse photographs taken during the minimum of solar activity or in the time immediately preceding it, and which may safely be considered as stationary streams of particles leaving the Sun. A stationary prominence is frequently observed at the base of such long streamers.

(*e*) The above-mentioned relation between prominences and coronal streamers fits in well with our present conception of the dynamics of prominences. When the corpuscular radiation is completely stopped off in a prominence, a momentum Nmv^2 is transferred to the latter, where N denotes the space-density of the particles, m their mass, and v their velocity. In a state of equilibrium this momentum must be equal to $g\sigma h$, where g is the gravita-

tional acceleration at the Sun's surface, σ the density, and h the height of the prominence. Taking $N = 10^9$, $m = 2 \times 10^{-24}$, $v = 6 \times 10^7$, $g = 2.7 \times 10^4$, $\sigma = 10^{-13}$, $h = 5 \times 10^9$, we obtain $Nmv^2 = 7.2$ and $g\sigma h = 13.5$. As both expressions are of the same order of magnitude, it is legitimate to suppose, that the prominence is supported by the corpuscular radiation absorbed by it.

The facts stated above having made it highly probable that there exists a direct relation between corpuscular radiation and the prominences, this relation has been further studied by different methods. Some of the results obtained are presented below [8].

The M-regions during the year 1930—The year 1930 appeared from different points of view as particularly favorable for the present investigation: (1) Bartels's diagram for this year shows two well-defined M-regions, which continued nearly through the whole year (Fig. 1, upper half); (2) sunspot-activity was on the whole insignificant and the zone of sunspots was confined to lower heliocentric latitudes; (3) only the principal prominence-region was apparent, at a heliocentric latitude of about 25° [9]. The upper part of Figure 1 shows the magnetic diagram with Bartels's indices 0, 1, . . . 5, for which only slightly modified symbols have been substituted. The prominence diagram reproduced in the lower half of Figure 1 was obtained in the following way: Using the "Immagini spettroscopiche del bordo solare", the prominence profile-areas on the east limb, P_E, and on the west limb, P_W, were determined in arbitrary units for every day. From these the prominence character-numbers for every day n, defined by the formula

$$P(n) = [P_E(n - 7) + P_W(n + 7)]/2$$

were computed. These character-numbers were divided into six groups, namely, index 0 for group $P < 20$, index 1 for $20 < P < 40$, index 2 for $40 < P < 60$, index 3 for $60 < P < 80$, index 4 for $80 < P < 100$, and index 5 for $P > 100$. These group-indices have been represented in the lower diagram of Figure 1 by the same symbols as the magnetic group-indices. The two M-regions, which correspond roughly to the 11th and 26th day, are beautifully reproduced by the diagram of prominences. It should be noted, however, that the diagram of prominences is displaced relatively to the magnetic diagram by six days, so that day n of the former corresponds to day $(n + 6)$ of the latter. If we denote by t_0 the moment, at which the source of the corpuscular radiation, as seen from the Earth, crosses the central meridian, and by t^* the moment at which this radiation reaches the Earth, then the time required for the arrival of the particles (= radius of the Earth's orbit/velocity), is given by

$$\tau = (t^* - t_0)\left(1 - \frac{\omega}{\Omega}\right) + \frac{\delta}{\Omega}$$

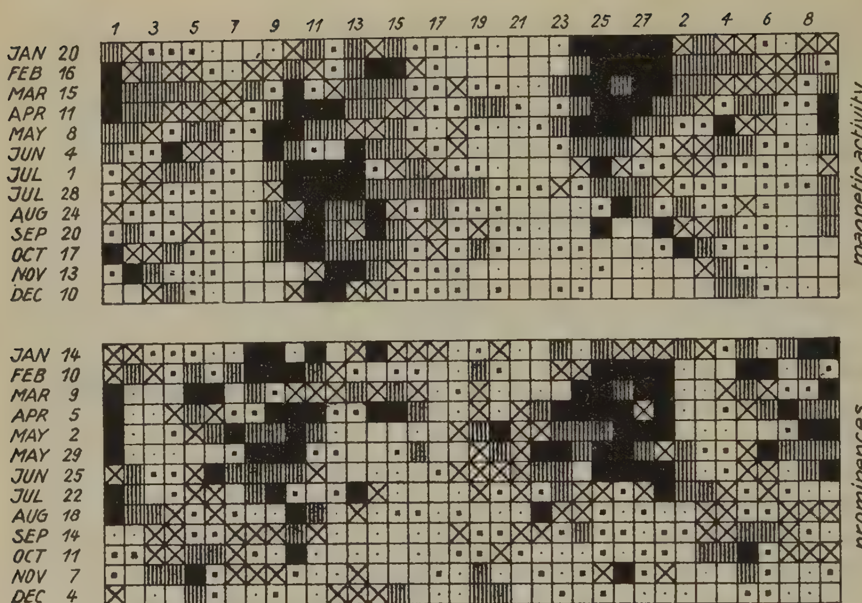

FIG. 1—DAY-BY-DAY RECORD OF MAGNETIC ACTIVITY AND SOLAR PROMINENCES FOR YEAR 1930

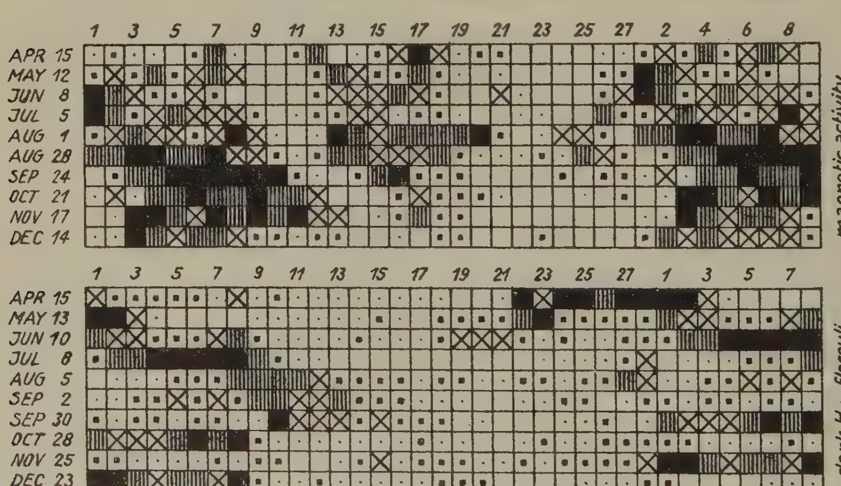

FIG. 2—DAY-BY-DAY RECORD OF MAGNETIC ACTIVITY AND DARK H_α-FLOCCULI FOR YEAR 1943

where ω designates the angular velocity of the Earth in its orbit ($\sim 1°$ per day), Ω that of the Sun ($\sim 14°$ per day), and δ the angle formed by the stream of particles at the Sun's surface with the radial direction to this surface. δ is positive when the particles are emitted forwards, that is, in the direction of the Sun's rotation. As nothing as yet is known about δ, we suppose the radiation to be directed radially and obtain for τ the value $\tau = 5^d.5$. The P_k-radiation turns out therefore to be much slower than the P_e-

radiation, for which a value $\tau = 1^d.5$ has been obtained. From the time just computed we deduce for the slow or continuous corpuscular radiation a velocity of roughly 320 km/sec. But the velocities obtained from different M-regions vary between values below 300 to above 600 km/sec so that there is a practically continuous transition between the velocity of the more rapid P_k-radiation and the lower component of the P_e-emission which, in the case of the great eruption of September 17, 1941, possessed a velocity of about 700 km/sec. For this reason an individual study of separate M-regions appears indispensable.

As a further example, giving rise to some new considerations, the analysis of the year 1943 is given below.

The *P_k-radiation during the year 1943*—As for 1930, conditions for the appearance of M-regions are likewise favorable for the year 1943, immediately preceding the minimum of solar activity. This year presents moreover the further advantage over 1930, that it possesses practically one unique M-region, which appeared in the second half of this year and could be traced up to the middle of 1944. The period from April 1943 to the end of 1943, with which we are concerned here, is presented in the magnetic diagram on Figure 2. The significance of the group-indices differs somewhat from that of Figure 1, in which Bartels's groups had been used. The group-indices, their graphical representations and corresponding magnetic character-numbers are: 0, open fields, 0.0 and 0.1; 1, small dots, 0.2 and 0.3; 2, large dots, 0.4, 0.5, and 0.6; 3, crosses, 0.7 and 0.8; 4, shaded field, 0.9 and 1.0; and 5, black field, $>$ 1.0. The observation of prominences made at Zurich, which are the only ones at the author's disposal at present, are too incomplete to allow of the construction of the corresponding diagram of prominences. Instead the character-numbers of dark H_α-flocculi for the whole of the Sun's disk, published in the "Quarterly Bulletin on Solar Activity," were used. As is well known, these dark H_α-flocculi, or filaments, are identical with the prominences observed at the Sun's limb. The above-mentioned character-numbers were likewise subdivided in six groups, which are represented in the prominence-diagram in Figure 2 by means of the same symbols as in the preceding diagram. The indices and corresponding character-numbers are: 0, $<$ 0.5; 1, 0.5 to 0.9; 2, 1.0 to 1.3; 3, 1.4 to 1.7; 4, 1.8 to 2.0; and 5, $>$ 2.0.

In the first half of 1943 sunspot-activity was particularly high between longitudes 160° and 170°, and attained its culminating point, and simultaneously its conclusion, in the first large group of the new cycle, which appeared in May at heliocentric latitude −40°. The prominence-activity usually accompanying the appearance of sunspot-groups was, in this case, particularly intense and persistent. This unusually rich prominence-region is very clearly shown in Figure 2, with its center falling approximately on the sixth day. As these prominences were mainly located between latitudes −50° and −60°, and possessed, therefore, considerably smaller angular

velocities than the spot-zone, the region occupied by them was shifted from one rotation to another more and more in the direction of decreasing longitudes. As most of the prominences observed in the second half of 1943 belonged, however, to this same center of disturbance, the above mentioned displacement could partly be taken into account by adopting a 28-day period for the prominence-diagram. Though the character-numbers of dark H_α-flocculi certainly represent a very unsatisfactory substitute for the prominences, the two diagrams in Figure 2 again show, nevertheless, a remarkable similarity. In both diagrams the center of the disturbance coincides with the sixth day, though it should be noticed that here, unlike Figure 1, the two diagrams have not been shifted with respect to one amother along the time-axis. On both diagrams, but especially on the prominence-diagram, there appears a drift of the region of disturbance, showing that the synodic rotation-period for the M-regions is somewhat greater than 27 days, and for the prominences considerably greater than 28 days. From this difference in the rotation-periods we conclude that in this particular case no direct relation between the prominences and the M-regions can be established. The formation of the M-region and the prominence-activity should on the contrary be regarded as two more-or-less independent consequences of the sunspot-group of May 1943. As the rotation-period of the M-region coincides with that of the above mentioned spot-group, we should look for it in the interval of longitude from 160° to 170°. This region always crosses the central meridian on the second day of the magnetic diagram. The magnetic disturbance begins, therefore, one to two days before the crossing of the central meridian by the M-region and is over eight to nine days after this event, whereas the middle of the disturbance occurs somewhere about the fourth day. In this case we again find, therefore, that the velocity of the particles is considerably smaller than that of the P_e-radiation, and just a little greater than that obtained for the M-region of the year 1930.

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Swiss Federal Observatory,
Zurich, Switzerland, August 10, 1946

PERIODICITY OF GEOMAGNETIC ACTIVITY

By A. Ogg

In a paper published in this Journal [51, 75-83, (1946)], which dealt chiefly with the correlation of the three-hour-range indices (K) at Hermanus with those at seven American-operated observatories, I drew attention to the question of the periodicity of the geomagnetic activity.

Periodograms which were published indicated in one group of K-indices periodicities of 9, 18, and 27 days, and in another group periodicities of 14 and 28 days. However, from the method, which was adopted in the search for periodicity, a high correlation-ratio for 18 and 27 days did not prove 18- and 27-day periods, if there existed a nine-day period in the group.

Shortly after the above article appeared Dr. J. Olsen of Copenhagen published a paper on "Persistent solar rotation period of 26.875 days and solar-diurnal variation in terrestrial magnetism" [Nature, 157, 621 (1946)]. He announced a persistent period of magnetic activity at Godhavn, Greenland, which was not the solar-rotation period.

Since these publications agreed that there existed periods of geomagnetic activity which were different from the period of rotation of the Sun, a further investigation was undertaken.

All the K-index data, which were collected at Cape Town and Hermanus covering an interval of six years—one year at Cape Town and five years at Hermanus—were used for the purpose. This investigation has verified the existence of periods which are one-half and one-third of the solar-rotation period.

Dr. Olsen in his investigation found a fixed solar-rotation period of 26.875 days and I have adopted the same value.

The material consisted of daily sums of K-indices during May 17, 1940, to May 3, 1946. They formed 81 sequences of 26.875 days. The 26.875-day sequences could be formed by seven sequences of 27 days followed by one of 26 days. It was found more convenient to deal with complete rows and one value was interpolated at the end of the 26-day row, that is one value every 215 days. The material was divided into three groups, each group covering an interval of about two years and consisting of 27 sequences. Smoothed curves I, II, III, and IV, as shown in Figure 1, of the variation of the sums of the daily columns from the mean of these columns were drawn and were harmonically analysed.

It is evident from Curve I, where the peaks of the positive variations are at 4, 13, and 22 days and the negative peaks of the curve are also nine days apart, that there is a nine-day period of magnetic activity in Group I. The harmonic coefficients determined by analyses of the magnetic variations in terms of K-indices for various groups are given in Table 1.

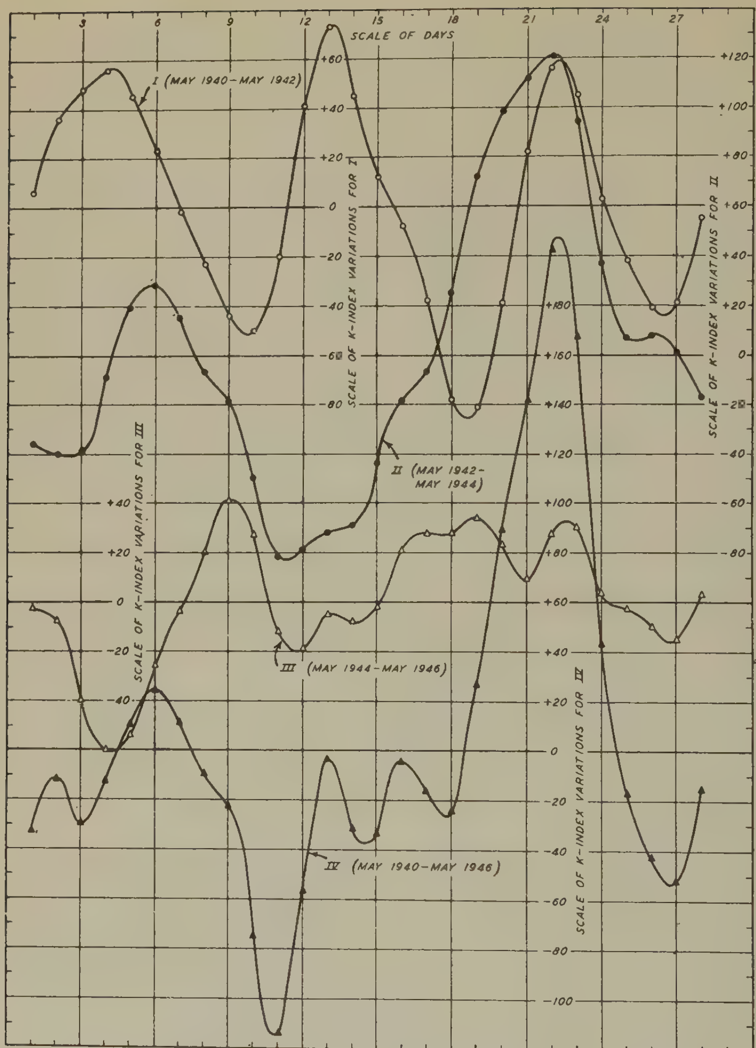

FIG. 1—SMOOTHED CURVES OF VARIATION OF K-INDEX VERSUS DAYS FOR TWO-YEAR GROUPS I TO IV

In Group I the amplitude of the third wave (9-day period) is three and one-half times greater than that of the first wave and more than four times that of any of the other waves.

In Group II the amplitudes of the first and second waves (27- and 13.5-day periods) are equal and are practically equal to that of the third wave in Group I.

Group III, which was near the sunspot minimum and of small magnetic activity, does not show any prominent wave. The amplitude of the first

TABLE 1—*Values of harmonic coefficients from analysis of 27-day (Groups I-IV) and 18-day (Group V) geomagnetic activity*

[In the series $\Sigma c_n \sin(nt + \varphi_n)$, t is measured in days from Greenwich zero hour of the first day of the epoch and converted into arc at the rate of 13°.5 for Groups I-IV and 20° for Group V per day.]

Group	Epoch	Sequences	Mean sums of daily cols.	Values of c_n and φ_n (Tabular values of c are in K-indices and of φ are in degrees)											
				c_1	c_2	c_3	c_4	c_5	c_6	φ_1	φ_2	φ_3	φ_4	φ_5	φ_6
I	May 17, 1940 to May 12, 1942	27	427	15	12	53	13	9	9	24	70	−84	11	11	−8
II	May 13, 1942 to May 7, 1944	27	457	55	55	8	11	9	9	145	260	238	69	95	81
III	May 8, 1944 to May 3, 1946	27	391	22	15	17	15	6	4	212	218	95	−14	−48	32
IV	May 17, 1940 to May 3, 1946	81	1275	58	55	43	30	12	9	153	252	270	16	19	111
V	May 17, 1940 to May 3, 1942	40	633	29	77	28	12	..	..	49	−83	−39	165	...	...

wave which is the largest, is only two-fifths of the large amplitudes of Groups I and II.

Compared with the largest amplitudes of Groups I and II all the amplitudes of the other waves are small but they are not negligible. For several days after a large magnetic storm it often happens that disturbances or small storms arise which would account for the short periods. The periodogram which was published in the former paper indicated a seven-day period.

The harmonic analysis of Group IV which is the total of the three consecutive groups, agrees well with the analyses of the individual groups. This indicates a fixed period of rotation of the Sun.

Reference has already been made to the 18-day period mentioned in the former paper. To test Group I for an 18-day period, Curve V of Figure 2 was derived in the usual way from 40 sequences of data in Group I, which contained one interpolated $\overline{K}$-index value every 215 days. The phase of the third wave of Curve I agrees with that of the second wave of Curve V as near as one-half hour, which is a good test of the adopted solar-rotation period. The analysis shows that the second wave (9-day period) is the prominent wave, but the first and third waves are not negligible.

This investigation has shown that there were periods of geomagnetic activity, which were one-third and one-half of the solar-rotation periods as well as the full period during these six years.

Dr. Olsen found a period, which was persistent throughout 15 summers, but the periods of this epoch were not persistent.

By using the international character-figure, C, instead of the K-index it was possible to detect a nine-day period in Group I, but periods in the other groups were not detected. The character-figure, C, is not suitable for this purpose.

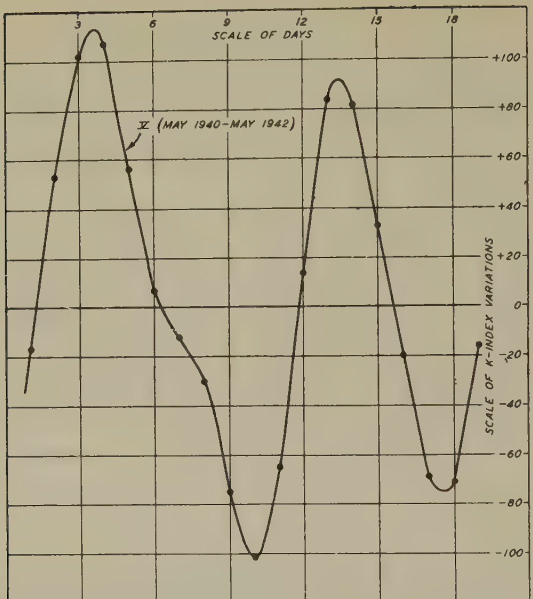

FIG. 2—SMOOTHED CURVE OF VARIATION OF K-INDEX VERSUS DAYS FOR TWO-YEAR GROUP V

I am indebted to A. M. van Wijk, Officer-in-Charge of the Hermanus Magnetic Observatory, for providing the necessary data.

Hermanus, C.P., South Africa, September 17, 1946

THE RADIAL STABILITY OF THE GEOMAGNETIC RING-CURRENT

(SECOND PAPER)

BY V. C. A. FERRARO

Abstract—An exact solution is given of an idealised problem, approximately treated by S. Chapman and the writer in an earlier paper dealing with the radial stability of a geomagnetic ring, in which the ring is replaced by an electrically neutral uniform cylindrical current-sheet whose axis is parallel to the magnetic axis of the Earth. The conclusions of that paper are substantiated, and though it is shown that the sheet is in reality unstable, the rate at which instability sets in is so slow that the sheet may well be considered to be stable. This rate is, moreover, comparable with the rate of decrease of intense and moderate magnetic storms.

§1. The radial stability of a geomagnetic ring-current was first considered in 1941 [see 1 of "References" at end of paper] by S. Chapman and the writer (in a paper hereafter referred to as *RS*). This dealt with an idealised cylindrical problem (see §2 below), and it was shown that, neglecting displacement currents, the current-sheet was stable for radial oscillations provided that certain conditions were satisfied. The effect of the neglect of the displacement currents on these conclusions was however not examined, nor were any additional conditions derived which might have to be satisfied for our approximation to be valid. The present paper gives an exact solution of the idealised cylindrical problem considered in *RS*. It is shown that the current-sheet is in reality unstable, though in all cases of geomagnetic interest the rate at which instability sets in is so slow that the sheet may well be considered to be, in effect, stable. The main conclusions reached in *RS* are therefore still valid.

§2. *The permanent magnetic field and the current-sheet*—As in *RS*, we replace the Earth's permanent magnetic field by a unidirectional, axially symmetrical field of intensity H, which, at a distance ω from the axis, is given by

$$H = H_0(a/\omega)^n \qquad (n > 2) \quad\ldots\ldots(1)$$

where a is the radius of the Earth. The lines of vector-potential, A, of the field are circles symmetrical about the axis. We have the relation given in (2).

$$A = -\omega H/(n-2) = -H_0 a^n/(n-2)\omega^{n-1} \quad\ldots\ldots(2)$$

The ring-current is replaced by an electrically neutral, uniform cylindrical current-sheet composed of equal numbers of positive ions and electrons. We denote their masses by m_i and m_e, their charges by e and $-e$,

and their lateral velocities by v_i and v_e. They have no motion parallel to the axis.

As in *RS*, it is advantageous to express v_i and v_e in terms of the mean mass velocity, v, and the differential velocity, v', defined by

$$m = m_i + m_e \qquad mv = m_i v_i + m_e v_e \qquad v' = v_i - v_e \quad \text{.....(3)}$$

Write also

$$m' = m_i m_e / m \quad \text{.....(4)}$$

Let also Q and $-Q$ denote the total positive and negative charges per unit-length of the sheet.

§3. *The equations of motion*—We suppose that the positive and negative charges do not separate during the motion [compare §3 of *RS* for the condition for this).

Let H'_+ and H'_- be the values of the magnetic field due to the current-sheet at points just outside and just inside the sheet, and let $\overline{H'}$ be the effective value of the magnetic field at any point of the sheet. Then

$$\overline{H'} = [(H'_+ + H'_-)/2] \quad \text{.....(5)}$$

Since the positive and negative charges keep together, there is only one radial equation of motion, namely

$$m\ddot{\omega} = (m_i v_i^2 + m_e v_e^2)/\omega + (ev'/c)(H + \overline{H'}) \quad \text{.....(6)}$$

or, by (3)

$$m\ddot{\omega} = [mv^2 + m'(v')^2]/\omega + (ev'/c)(H + \overline{H'}) \quad \text{.....(7)}$$

From the equations of angular momentum for the positive and negative changes we derive [compare §4 of *RS*] equations (8) and (9).

$$m_i \omega v_i + e\omega(A + A')/c = \text{constant} \quad \text{.....(8)}$$

$$m_e \omega v_e - e\omega(A + A')/c = \text{constant} \quad \text{.....(9)}$$

A' being the vector-potential due to the current-sheet.

From these we derive the equivalent relations

$$\omega v = K \quad \text{.....(10)}$$

$$\omega v' = K' - \left(\frac{e\omega}{m'c}\right)(A + A') \quad \text{.....(11)}$$

where K and K' are constants [the latter not being equal to K' in equation (4.8) of *RS*].

§4. *The steady state*—In the steady state $\ddot{\omega} = \dot{\omega} = 0$; let $\omega = \omega_0$ be the radius of the current-sheet in this state and denote the corresponding values of v and v' by V and V'. Then we have by (7)

$$[mV^2 + m'(V')^2]/\omega_0 = -(eV'/c)(H_0 + \overline{H_0'}) \quad\ldots\ldots\ldots\ldots(12)$$

where $\overline{H_0'}$ denotes the uniform magnetic field produced by the current-sheet in the steady state. Since [compare §4 of *RS*] $\overline{H_0'} = QV'/\omega_0 c$, this equation may be written in the form

$$[mV^2 + m''(V')^2]/\omega_0 = -(eV'/c)H_0 \quad\ldots\ldots\ldots\ldots\ldots\ldots(13)$$

where $m'' = (m' + eQ/c^2)$.

§5. *The field variables*—We suppose that the cylindrical symmetry of the motion is preserved in a slightly disturbed state in which we suppose the radius ω and the velocities v and v' to be given by

$$\omega = \omega_0 + \omega_1 \qquad v = V + V_1 \qquad v' = V' + V_1' \quad\ldots\ldots\ldots(14)$$

where V and V' satisfy (12), and ω_1, V_1, V_1' are small. Let also

$$H = H_0 + H_1 \qquad H' = H_0' + H_1' \quad\ldots\ldots\ldots\ldots\ldots\ldots(15)$$

where H_0' is the steady state value of H', and H_1 and H_1' are small.

We now assume that ω_1, V_1, V_1' are proportional to e^{-ipt}; it then follows from the equations of motion in §3 that H_1' varies as e^{-ipt} also, and since there are no radial or axial components of A, Maxwell's equations indicate that H_1' satisfies the equation

$$\frac{d^2H_1'}{d\omega^2} + \left(\frac{1}{\omega}\right)\left(\frac{dH_1'}{d\omega}\right) + \left(\frac{p^2}{c^2}\right)H_1' = 0 \quad\ldots\ldots\ldots\ldots\ldots\ldots(16)$$

or

$$\frac{d^2H_1'}{dx^2} + \left(\frac{1}{x}\right)\left(\frac{dH_1'}{dx}\right) + H_1' = 0 \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots(17)$$

namely, Bessel's equation of order zero, wherein

$$x = p\omega/c \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(18)$$

Since the electromagnetic field within the sheet is everywhere finite, and at infinity has the character of a divergent wave, the appropriate values of H_1' within and outside the sheet are given by

$$H_1' = CH_0^{(1)}(p\omega/c)e^{-ipt} \qquad (\omega > \omega_0) \quad\ldots\ldots\ldots\ldots\ldots(19)$$

$$= DJ_0(p\omega/c)e^{-ipt} \qquad (\omega < \omega_0) \quad\ldots\ldots\ldots\ldots\ldots(20)$$

where $J_0(x)$ is Bessel's function of order zero and $H_0^{(1)}(x)$ is Hankel's function of the first kind and of order zero. The corresponding values of the vector-potential A are given by

$$A = \left(\frac{c}{p}\right) C H_1^{(1)}(p\omega/c)e^{-ipt} \qquad (\omega > \omega_0) \quad \text{.................(21)}$$

$$A = \left(\frac{c}{p}\right) D J_1(p\omega/c)e^{-ipt} \qquad (\omega < \omega_0) \quad \text{.................(22)}$$

The scalar potential is everywhere zero; finally it follows at once from (1) that

$$H_1 = -nH_0\omega_1/\omega_0$$

§6. *The boundary conditions* to be satisfied are that A should be continuous across the sheet, $\omega = \omega_0$, and that the discontinuity of the magnetic field across the sheet should be equal to 4π times the current. These give respectively the equations

$$DJ_1(p\omega_0/c) = CH_1^{(1)}(p\omega_0/c) \quad \text{.........................(23)}$$

$$[DJ_0(p\omega_0/c) - CH_0^{(1)}(p\omega_0/c)]e^{-ipt} = 2QV_1'/\omega_0 c \quad \text{.............(24)}$$

to determine the unknown constants C and D.

§7. *The period equation*—Substituting the values of ω, v, v' given by (14) in the equations of motion (7), (10), and (11) and retaining only terms of the first order, and making use of the equations for the steady state (§4) and those of the field variables (§§5 and 6) we find, after some reduction, the following equation for

$$i(x^2 - \lambda\nu\sigma) = \pi\lambda[(x^2 - a^2)J_1(x) + \nu x J_0(x)]H_1^{(1)}(x) \quad \text{.........(25)}$$

where x now stands for $(p\omega_0/c)$. The remaining quantities in this equation are given by

$$\nu = (V/c)^2 \qquad \lambda = eQ/m'c^2$$

$$\sigma = 1 + \frac{e\omega_0^2(H_0 + \overline{H_0'})^2}{mQV^2} + \frac{ncm'\omega_0 V'H_0}{mQV^2} \quad \text{.................(26)}$$

and

$$mc^2a^2 = 3mV^2 + m'(V')^2 + ne\omega_0 V'H_0/c \quad \text{...............(27)}$$

The condition that the steady motion should be stable for radial displacements is that the values of p, and hence the roots of (25), should be real or else have their imaginary parts negative; but all such complex roots must be rejected as they yield infinite values of the field at infinity.

It will be seen at once that (25) possesses, at most, two real roots. For, if x is real, remembering that $H_1^{(1)} = (J_1 + iY_1)$, we have, on equating real and imaginary parts of (25), the simultaneous equations of (28).

$$[(x^2 - a^2)J_1 + x\nu J_0]J_1 = 0 \qquad x^2 = \lambda\nu\sigma \quad \text{......(28)}$$

The first equation is satisfied by the roots of the equation $J_1(x) = 0$, or by the roots of the equation $[(x^2 - a^2)J_1 + x\nu J_0] = 0$; these roots are known to be all real. Thus, $\pm\ (\lambda\nu\sigma)^{\frac{1}{2}}$ must satisfy the first equation in (28), and, in general, this will not be possible.

A general discussion of the location of the roots of (25) is difficult; in our case, however, this is not essential, because in geomagnetic applications the values of the constants λ, ν, σ are such that, excepting small roots, we may readily prove that any complex root of (25), if it exists, has a negative imaginary part. From the numerical illustrations considered in §§8-10 of *RS*, we find, for the case when $V = 10^8$ cm/sec that $\nu \sim 1.1 \times 10^{-5}$, $\lambda \sim 10^6$ to 10^8, σ is of the order 10, and a^2 is of order ν or $a^2 \sim 10^{-5}$.

Considering first large roots of (25), that is, supposing $|\ x\ | \gg 1$, we may replace the Bessel functions in (25) by their asymptotic expansions, retaining only the first term in each case. We find, approximately, that (25) becomes

$$i(x^2 - \lambda\nu\sigma)$$
$$= \frac{2\lambda}{x}\left[(x^2 - a^2)\cos\left(x - \frac{3}{4}\pi\right) + \nu x \cos\left(x - \frac{1}{4}\pi\right)\right]e^{i(x-3/4\pi)} \quad \text{.......(29)}$$

Since a^2 and ν are small in comparison with x, we may neglect them in this equation. Writing also $y = (x - \frac{3}{4}\pi)$ we find this equation becomes approximately

$$i\left(x - \frac{\lambda\nu\sigma}{x}\right) = \lambda(e^{2iy} + 1) \quad \text{.........................(30)}$$

Let $y = (\xi + i\eta)$ for ξ and η real, $\xi_1 = (\xi + \frac{3}{4}\pi)$ so that $x = (\xi_1 + i\eta)$ and equating real and imaginary parts, we find

$$\lambda + \eta\left(1 + \frac{\lambda\nu\sigma}{\xi_1^2 + \eta^2}\right) = -\lambda e^{-2\eta}\cos 2\xi$$

$$\xi_1\left(1 - \frac{\lambda\nu\sigma}{\xi_1^2 + \eta^2}\right) = \lambda e^{-2\eta}\sin 2\xi$$

whence, on squaring and adding

$$\left[\lambda + \eta\left(1 + \frac{\lambda\nu\sigma}{\xi_1^2 + \eta^2}\right)\right]^2 + \xi_1^2\left(1 - \frac{\lambda\nu\sigma}{\xi_1^2 + \eta^2}\right) = \lambda^2 e^{-4\eta}$$

It is easy to see that $\eta < 0$; for if $\eta \geq 0$ the two sides of the equations would be one greater than, the other less than λ^2. Thus there can be no complex roots of large modulus whose imaginary parts are positive [2].

Considering next the case when $|x|$ is of order unity, we may here also neglect a^2 and the term $\nu x J_0$ in the bracket of the right-hand side of (25); since $\lambda\nu\sigma \gg 1$, we may neglect x^2 compared with $\lambda\nu\sigma$; and (25) becomes approximately

$$-\nu\sigma i = 2x^2 J_1 H_1^{(1)} \qquad (31)$$

Since $\sigma\nu$ is small (of order 10^{-4}) in all cases of interest for geomagnetism it follows that $|J_1|\,|H_1^{(1)}| \ll 1$. From tables of values of $J_1(x)$ and $H_1^{(1)}(x)$ for complex arguments, x, it is seen that $|J_1|\,|H_1^{(1)}|$ is not small when $|H_1^{(1)}|$ is small. Thus any root of (31) must be such that $|J_1| \ll 1$, and therefore the complex roots of (25), for which $|x|$ is of order unity, if they exist, must lie near the zeros of $J_1(x)$. We may express any such root x in the form $(x_0 + x_1)$ where x_0 is a zero of $J_1(x)$ and x_1 is small.

Substituting in (31), and neglecting powers of higher than the second, an approximate root of (31) in the neighborhood of $x = x_0$ is

$$x = x_0 + \left(\frac{\pi\nu\sigma}{4x_0}\right)\left[1 - \left(\frac{1}{2x_0} + \frac{J_0 + iY_0}{iY_1}\right)\left(\frac{\pi\nu\sigma}{4x_0}\right)\right] \qquad (32)$$

where the arguments of the Bessel functions is x_0. If $x_0 > 0$ the imaginary part of x is given by

$$I(x) = -\left(\frac{2}{\pi x_0 Y_1^2}\right)\left(\frac{\pi\nu\sigma}{4x_0}\right)^2$$

using $x_0 J_0 Y_1 = -(2/\pi)$. It is seen at once that $I(x) < 0$ and is very small, being of the order of 10^{-8}. If $x_0 < 0$, we must first consider the values of $Y_0(x_0)$ and $Y_1(x_0)$; these may be derived from the relation [3]

$$Y_n(xe^{m\pi i}) = e^{-mn\pi i} Y_n(x) + 2i \sin mn\pi \cot n\pi J_n(x)$$

Since $J_1(x_0) = 0$ it follows that $Y_1(x_0)$ is real; also since the field variables are single valued functions, we must restrict $Y_n(x)$ to its principal branch for which arg log $x (= \theta)$ is restricted to the range

$$-\pi < \theta \leq \pi$$

It then follows from the above relation that

$$Y_0(x_0) = Y_0(-x_0) \pm 2iJ_0(-x_0)$$

the positive or negative sign being taken according as arg x_0 is taken equal to π or $-\pi$. By continuity, this will be the case according as $I(x) > 0$ or < 0.

Suppose $I(x) > 0$, so that $\arg x_0 = \pi$; then we find (using the relation $x_0 J_0 Y_1 = -2/\pi$) that

$$I(x) = \left(\frac{2}{\pi x_0 Y_1^2}\right)\left(\frac{\pi \nu \sigma}{4 x_0}\right)^2$$

which is a small negative quantity of the order of 10^{-8}, since $x_0 < 0$. We thus arrive at a contradiction. Suppose next $I(x) < 0$, so that $\arg x_0 = -\pi$; we then find

$$I(x) = -\left(\frac{6}{\pi x_0 Y_1^2}\right)\left(\frac{\pi \nu \sigma^2}{4 x_0}\right)$$

which is a small positive quantity, and we arrive again at a contradiction. It follows therefore that there exist no complex roots of (31) whose real part is negative. Thus, excepting small roots, all complex roots of (25), if they exist, possess negative imaginary parts and must be rejected.

It follows from the above that the only roots of (25) of physical interest are those which are numerically small, and for which, therefore, $(p\omega/c)$ is small at all field points not at large distances from the axis. For small values of the argument we may use the following approximations: $J_0(x) \sim 1$, $J_1(x) \sim (x/2)$, $H_1^{(1)} \sim -(2/\pi) \log (2/\gamma x)$, where γ is Euler's constant, and $H_1^{(1)\prime}(x) \sim -(2/\pi x)$. It is then seen from (19) to (22) that the values of H' and A' agree with those first derived by S. Chapman and the writer in an earlier paper [4], and used in *RS*, except that H' is not strictly zero outside the sheet; however, the constant C occurring in (19) and (21) is small compared with D when $(p\omega_0/c)$ is small, and this being the case, the assumption was justifiable. The conclusions regarding the stability of the current-sheet for radial oscillations, however, do not strictly hold good, as will be seen from the solution of (25) in the case when x is small. Using the above approximations for the Bessel's functions near the origin, we find as a first approximation

$$x^2 = [\lambda\nu(\sigma - 2) + \lambda a^2]/(1 + \lambda)$$

or since $\lambda \gg 1$

$$x^2 = \nu\sigma - 2\nu + a^2$$

The corresponding value of p, say $p = p_0$, is found to be given by

$$p_0^2 = \left(\frac{eH_0}{c}\right)^2\left(\frac{1}{mm''}\right) + \left(\frac{neV'H_0}{m\omega_0 c}\right) - \left(\frac{eV'\overline{H_0'}}{m\omega_0 c}\right) \qquad (33)$$

which agrees with equation (6.3) of *RS* except for the presence of the last term. The difference is accounted for by the fact that in *RS* the magnetic

field outside the sheet was supposed to be zero. Replacing m'' by (eQ/c^2), as is legitimate, and using the equation $H_0' = (QV'/\omega_0 c)$ this may be written

$$p_0^2 \sim (e/mQ)\left[H_0^2 + \left(\frac{n}{2}\right)H_0\overline{H_0'} - (\overline{H_0'})^2\right] \qquad (34)$$

which now replaces (10.1) of *RS*.

Since in all cases arising in our problem $\overline{H_0'}/H_0 \ll 1$ the error in (6.3) of *RS* is small.

The condition that $p_0^2 > 0$ now becomes somewhat more complicated than the corresponding one in *RS*; it is

$$H_0 > -\left[\frac{n}{4} + \left(1 + \frac{n^2}{16}\right)^{\frac{1}{2}}\right]\overline{H_0'} \qquad (35)$$

which for $n = 3$ reduces to $H_0 > -2\overline{H_0'}$; this replaces the condition 8.1 of *RS*.

Assuming (35) to be satisfied, a second approximation to p is given by

$$p^2 = p_0^2(1 + 2i\epsilon) \qquad (36)$$

where

$$\epsilon = (\pi e\omega_0 V'/8mc^3)(nH_0 - H_0 - \overline{H_0'}) \qquad (37)$$

is a small quantity which, for $n > 1$, is negative. Since we require only complex roots whose imaginary part is positive, the requisite solution of (36), and hence of (25), is approximately

$$p = -p_0(1 + i\epsilon)$$

where $p_0 > 0$.

§9. *The rate at which instability sets in*—Using (12), and neglecting $m'(V')^2$ in comparison with mV^2 in this equation, we may write approximately

$$\epsilon = (\pi V^2/8c^2)\left(1 - \frac{nH_0}{H_0 + \overline{H_0'}}\right)$$

Thus, unless $(H_0 + \overline{H_0'})$ is very small, ϵ will be of the order of (V^2/c^2) and therefore small so long as $V \ll c$.

Since ω_1 varies as e^{-ipt} and the imaginary part of p is small, the radial oscillations may be regarded as simple harmonic vibrations whose amplitude increases steadily with t like the factor $e^{-p_0\epsilon t}$. The amplitude therefore increases in the ratio $1 : e$ in a time $t_0 = -(1/p_0\epsilon)$.

As a numerical illustration, we consider the examples of §10 in *RS*. In the first of these we suppose $\overline{H_0'} = -40\gamma$, $\bar{H}_0 = 240\gamma$, $\omega_0 = 5$ earth radii, and $V = 10^8$ cm/sec; then $p_0 = 0.1$ very nearly, and for $n = 3$, $p_0\epsilon \sim -10^{-6}$.

The corresponding value of t_0 is 10^6 seconds or 11 days. Secondly, suppose $\overline{H'_0} = -40\gamma$, $H_0 = -940\overline{H'_0}$, $\omega_0 = 2$ earth radii, and $V = 10^8$; then $p_0 = 3$ and, for $n = 3$, $p_0\epsilon \sim -2 \times 10^{-5}$. The corresponding value of t_0 is 5×10^4 seconds or one half-day.

It is at once apparent that the rate at which instability sets in increases as ω_0 decreases, that is, for geomagnetic rings which are nearer the Earth. This rate, however, is sufficiently slow for the conclusions reached in *RS* to be still considered justifiable.

It is of interest to note that the rate of decay of the current sheet deduced above is of the order of the rate of decrease of intense and moderate storm-effects on D_m.

§10. *Conclusion*—The above investigation has shown that the solution of the problem given in *RS*, in which the displacement currents are neglected, is approximately valid provided that $(p\omega_0/c)$ and (V/c) are both small compared with unity. We can see in a simple way why these two conditions must hold: the neglect of the displacement current implies that the propagation of the field affecting the motion of a charged particle of the sheet must be nearly instantaneous. For this to be the case, the time of travel of a disturbance across a diameter of the sheet $(= 2\omega_0/c)$ must be small compared with (*i*) the period of the radial oscillations $(= 2\pi/p_0)$ [see 5] and (*ii*) the time taken by a charged particle to travel once round the sheet $(= 2\pi\omega_0/V)$; this amounts to the two above conditions being satisfied.

If these conditions are not satisfied (in addition to the condition that p_0 should be real) there can be little doubt that the sheet will be ordinarily unstable, probably tending to dissipate itself outwards.

It is hoped to consider in a later paper this and other questions connected with the general stability of a geomagnetic ring-current.

References

[1] Terr. Mag., **46**, 1-6 (1941).

[2] Approximate expressions for complex roots of large modulus can be readily obtained from these equations, but these need not be given here.

[3] G. N. Watson, Theory of Bessel Functions, p. 75 (1922).

[4] Terr. Mag., **45**, 245-268, §2.7 (1940).

[5] This condition is also equivalent to the condition that the wave-length of the electromagnetic disturbances should be large compared with a radius of the sheet.

King's College, University of London,
Strand, W.C. 2, London, England, October 8, 1946

LETTERS TO EDITOR

(See also pages 500 and 577)

INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS

The first General Assembly of this Council since the war has just concluded its meetings, which were held at the rooms of the Royal Society, London, under the Presidency of Dr. H. R. Kruyt of Utrecht University. Over seventy representatives of the principal Scientific Academies, of a number of National Research Councils, and of the various International Scientific Unions were present. The countries officially represented were Australia, Belgium, Canada, China, Czechoslovakia, Denmark, Egypt, France, Great Britain, India, Italy, Netherlands, Netherlands East Indies, New Zealand, Norway, Peru, South Africa, Sweden, Switzerland, United States, and Yugoslavia. In addition as guests a welcome was extended to Monsieur A. Establier and Madame Malterre of the International Organisation of Intellectual Cooperation of the League of Nations and Dr. Needham head of the Scientific Division of the Preparatory Commission of the United Nations Educational, Scientific, and Cultural Organisation (UNESCO).

The President in his address mentioned the heavy losses that the Council had suffered by death since its last meeting in 1937. The Executive Committee alone had lost its President, Prof. Fabry; two Vice-Presidents, Il Marchese Marconi and Baron Joji Sakurai; Professor H. Abraham, General Bourgeois, Sir Arthur Eddington, Professor Parravano, General Perrier, Dr. Philippson, and Sir Albert Seward, officers of the separate Unions which they represented on the Executive Committee.

The President explained the functions of the Council as the international organisation coordinating the national academies and the scientific Unions. Its immediate task was to stimulate the formation of Unions in branches of science where no Union at present existed and to organize scientific activities in those borderland domains which are intermediate between those of two or more Unions. The existing committee of the Council on Solar and Terrestrial Relationships provided a good example of what results could be obtained from these intermediate fields of knowledge. It was proposed to make the Committee a joint commission of the Unions of Astronomy, of Geodesy and Geophysics, and of Radio Science. New joint commissions and new Unions were in view.

There had been discussions with the Scientific Division of UNESCO on the possibility of cooperation within their respective fields and a draft agreement would be submitted to the meeting and referred to UNESCO for ratification later in the year. This new agreement would replace the one

officially made in 1937 with the International Organisation of Intellectual Cooperation of the League of Nations with whom for a short time they had had very happy relations. The war had cut right across their schemes for mutual assistance and the agreement had been terminated by notice from the Organisation, which would cease to exist when UNESCO came into being.

The Assembly would also be discussing problems arising from the impact of scientific research on the life of the community and also the ethical responsibility of the individual Scientist. He hoped that the result of their discussions would be to give this meeting an honorable place in the history of the International Council.

The opening session after the welcome by Sir Robert Robinson, President of the Royal Society, and the President's address was devoted to a general discussion of the future development of the Council's activities and of the policy to be pursued. The general effectiveness of small Unions and of large Unions with specialised Sections or Associations was fully discussed; the President summed up the discussion by saying that the Unions existed to coordinate the activities of the scientific workers and that the problem of separation or union could be left to work itself out later.

The second session was devoted to the draft agreement with UNESCO. As this has not yet been ratified by UNESCO full details cannot be given; it may be stated, however, that it involves recognition of the Unions and Council by UNESCO (and of UNESCO by the Council); close consultative relations between the Council and UNESCO, offers of help from UNESCO to ease the administrative burden that now falls on the Secretaries of the Council and Unions; assistance both financial and other in getting scientific persons to conferences and symposia; and financial assistance in some of the major projects of the Unions.

At the third session Reports were read from all the Unions indicating that they had already begun to restart their prewar activities, so far as these had necessarily been dropped during recent years, or that they were to hold their initial postwar meetings as soon as proved practicable. On the whole the reports sounded a more cheerful and hopeful note than had seemed likely in advance; despite the recent difficulties that the Unions had been facing, international cooperative work had continued wherever possible and much fresh work was in prospect.

A resolution proposed by Professor Hadamard on the difficulties arising from the restrictions imposed by the exchange control on the free interchange of scientific publications was referred to the Executive Committee for discussion with UNESCO.

Amendments of the Statutes followed. The more important changes were (1) the speeding up of the working of the Council by giving to the Executive Committee powers previously kept in the hands of the General

Assembly, (2) an increase in the unit of subscription from the adhering countries. The latter was needed to meet the increased activities called for on the part of the Executive Committee—more frequent meetings and reports.

The fourth session was devoted to the reports of two committees of the Council. Professor Abetti presented the report of the Committee on Solar and Terrestrial Relationships: the *Quarterly Bulletin of Solar Character-Numbers* had now been published up to 1944. Of the present separate character-number of the Sun only the sunspot-number would be given in future *Bulletins;* details of solar eruptions would continue to be published and fresh solar data, especially coronal phenomena now made available by the pioneer work of Lyot.

Professor J. M. Burgers presented and summarised the report of the Committee on Science and Social Relations (CSSR). He explained that, owing to the difficulties of communication and the short time available to gather in the material asked for by the Executive Committee, there had been no time for discussion by the CSSR itself.

A vigorous discussion followed on resolutions submitted by the Committee and an additional resolution proposed by Dr. A. V. Hill. Reference was made in the discussion to the remarks of the President of the Royal Society in his address to the Council at its opening meeting: his final passage may here be quoted:

> The prevailing spirit among scientists at the present time should surely be one of hope and optimism. Opportunity knocks at the door. We may well be at a critical point in history the turning of which cannot be accomplished without our assistance.
>
> This Council is in a unique position to focus our efforts to maximum intensity and that is why I have ventured to emphasise the necessity for circumspection and the dangers of an attitude of aloofness from the body politic.
>
> Wisely used the most pervasive faith in the world, the religion of the pursuit of truth for its own sake, may be the most potent instrument of reconciliation and reconstruction. Thus we may help to lead the nations into amity and the prosperity which flows from long continued peace.

In the light of the discussion the CSSR was asked to revise its draft report and in consultation with the Bureau of the Council to amend slightly the wording of the resolutions.

At the final meeting the resolutions as given below were adopted unanimously after Professor Niels Bohr had given his support, Dr. Hill had quoted Sir Henry Dale as being cordially in favor, and Col. Dianderas had approved the resolutions in the name of the Government, the Universities, and the men of science of Peru and more generally as a representative of South America.

The resolutions, as adopted, follow:

(1) The General Assembly of the International Council of Scientific Unions sees in the great powers for good or evil that research on

nuclear energy has put at the disposal of mankind a supreme opportunity and occasion for a new international unity, to develop the benefits potential in nuclear energy and to avoid its misuse. The General Assembly strongly supports the efforts now being made under the auspices of the United Nations to attain this urgent goal, efforts in which the cooperation of representative men of science, so essential for success, is being officially given. The General Assembly urges that the present opportunity of eliminating war by the attainment of such a new international unity be grasped.

The General Assembly hopes that the attainment of an agreement on the application of nuclear energy may provide an important instance of international cooperation in economic and political matters. Extension of this would facilitate the promotion of the welfare of mankind, the judicious use of our natural resources, the removal of causes of dispute, and the settling of difficulties arising from the continuous change of world conditions in consequence of scientific and technical advances.

(2) The General Assembly is aware that nuclear energy is not unique among scientific advances in its possible effects for good or ill. Biological and biochemical warfare, for example, was not applied during the late conflict, but its potential menace may be as great as that of the atomic bomb; equally, the discoveries on which it depends could bring the greatest benefits to mankind.

The General Assembly is convinced that international security and welfare will be impossible if in any country for the future military secrecy is allowed to dominate scientific discovery or to prevent the frank discussion and open publication of scientific results. "There can be no international control and no international cooperation which does not presuppose an international community of knowledge."

(3) The General Assembly of the International Council of Scientific Unions, in the name of the men of science of the nations represented, acknowledges the duty on the part of scientific workers:

- (*a*) To maintain a spirit of frankness, honesty, integrity and cooperation and to work for international understanding;
- (*b*) To promote the development of science in the way most beneficial to mankind and to exert their influence as far as possible to prevent its misuse;
- (*c*) To serve the community not only by their specialized work but by assisting so far as they are able in the education of the public in the purposes and achievements of science.

An invitation from the Royal Danish Academy to hold the next meeting of the General Assembly in Copenhagen in 1949 was accepted with acclamation.

The following were elected as the members of the Bureau:

President: Dr. J. A. Fleming, adviser to the Carnegie Institution in governmental and international scientific relations

Vice-Presidents: Professor B. Nemeč, Prague, and Professor Emile Borel, Paris

Members: Dr. J. N. Mukherjee, New Delhi, and Professor H. Solberg, Oslo

General Secretary: Professor F. J. M. Stratton, Cambridge

Retiring President: Dr. H. R. Kruyt, Utrecht

Vote of thanks to the Royal Society and to Dr. Kruyt brought the meeting to a close.

F. J. M. Stratton, *Secretary*

Gonville and Caius College,
Cambridge, England, July 30, 1946

FIVE INTERNATIONAL QUIET AND DISTURBED DAYS FOR JANUARY TO MARCH, 1946

Reports of geomagnetic activity for the first quarter of 1946 have been received from a sufficient number of observatories so that the International quiet and disturbed days can be selected in accordance with the method outlined on pages 219-227 in the December, 1943, issue of this Journal. The selection is based on the reports of magnetic character on a scale of 0, 1, and 2 from 35 observatories and of K-indices from 28 observatories.

Month	Quiet					Disturbed				
January	9	13	14	20	21	3	4	11	24	26
February	1	11	26	27	28	7	8	14	19	21
March	3	12	13	14	16	10	22	24	25	28

Department of Terrestrial Magnetism,
Carnegie Institution of Washington,
Washington 15, D. C., October 16, 1946

W. E. Scott

SOLAR AND MAGNETIC DATA, JULY TO SEPTEMBER, 1946, MOUNT WILSON OBSERVATORY

An immense complex bipolar sunspot-group, Mount Wilson No. 8129[1], crossed the solar disk from July 19 to August 2. Its maximum area, measured at the United States Naval Observatory, was 3685 millionths of a solar hemisphere (4325 million square miles). A small flare was observed at Mount Wilson over the group on July 21 at 15^h11^m GCT and a very intense one on July 25 from 16^h21^m to 18^h30^m.

On July 26, a great magnetic storm began at 18^h47^m (from Tucson magnetogram), more than 26 hours after the appearance of the bright flare of July 25 which showed on a spectroheliogram at 16^h21^m but not on one at 16^h05^m. An aurora, observed at Mount Wilson near midnight of July 26 (July 27^d08^h), and the small magnetic storm on July 29-30 also were probably associated with this immense group.

TABLE 1—*Magnetic storms*

Greenwich civil time						Range in *H*
Beginning			Ending			
1946	*h*	*m*	*d*	*h*	*m*	γ
July 7	03	25*	07	13	..	105
July 26	†	..	27	13	..	†
July 29	01	36	30	18	..	170
Aug. 13	19	01	15	06	..	125
Aug. 30	22	40*	31	11	..	155
Sept. 17	23	40*	19	17	..	185
Sept. 22	04	24*	24	01	..	330
Sept. 28	03	..	29	05	..	140

*Sudden commencement. †Time of beginning and range in *H* unknown because the power was off from 08^h to about 19^h.

When group No. 8129, renumbered 8163, returned to the east limb on August 16, it was greatly diminished in area, although still visible without a telescope. No magnetic storm occurred between August 16 and 30 during its transit across the Sun's disk, but the storm of August 30-31 may have been associated with its activity.

Many sunspot-groups were present during the magnetic storms of September but it is impossible to say definitely which groups, if any, were associated with these storms. The groups most probably associated with the storm of September 17-19 were No. 8191, 33° west, and No. 8193, 24° east, when the storm began. Those most probably associated with the great storm of September 22-24 were No. 8193, 33° west, and No. 8197, 16° east, when the storm began.

[1]Pub. Astron. Soc. Pacific, 58, 315 (1946).

TABLE 2—*Solar and magnetic data*

Day	July 1946						August 1946						September 1946					
	K_2		H_α	H_α	No.	Mag'c	K_2		H_α	H_α	No.	Mag'c	K_2		H_α	H_α	No.	Mag'c
	Whole disk	Central zone	bright	dark	groups	char.	Whole disk	Central zone	bright	dark	groups	char.	Whole disk	Central zone	bright	dark	groups	char.
1	3	1	2	3	12	0	4	3	4	3	9	0	4	3	3	3	12^g	0
2	2	1	3	3	11	0	4	3	4	3	$9^{e,j}$	0	..	..	..	..	11	0
3	3	1	3	3	7	0.5	3	3	3	3	8^k	0	4	2	3	2	13	0
4	3	2	3	2	6	0	3	2	3	2	9	0	3	3	3	2	11	0.5
5	3	3	3	2	7^h	0	3	1	3	2	8	0	3	3	3	2	6	0
6	3	4	4	2	8	0	3	1	3	2	11^b	0	3	3	3	2	5	0
7	3	4	3	3	9^j	1	3	2	3	2	8	0.5	3	3	3	3	5	0.5
8	3	3	3	3	8	0.5	3	3	2	2	9	0.5	3	2	3	3	6	0
9	3	1	3	2	6	0.5	3	3	2	2	8	0.5	3	2	3	3	4	0.5
10	2	1	2	3	6	0	3	3	3	2	8^i	0	3	2	3	4	7^b	0.5
11	3	1	3	3	8^b	0	4	3	3	2	7	0.5	3	2	3	4	5^b	0
12	2	2	2	2	9	0	4	3	3	2	8	0.5	..	..	..	..	6	0
13	2	2	2	1	5	0	3	2	3	2	8	0.5	3	3	3^c	4	6	0
14	3	3	2	1	6^b	0.5	3	3	3	3	12	1	4	3	3	4	6	0
15	3	3	3	1	7^b	0.5	3	3	3	3	11	0.5	4	3	3	4	6^e	0
16	3	3	3	2	9	0	3	3	3	3	12	0.5	4	3	3	1	7	0.5
17	3	3	3	2	10	0.5	3	3	3	4	8	0.5	4	4	3^d	1	6	0.5
18	3	3	3	3	11^h	0.5	3	2	3	4	8	0	3	4	3	1	8^b	2
19	3	2	..	..	11	..	4	2	3	4	5	0	3	3	3	1	8^g	1.5
20	3	2	3	3	9	0	4	4	3	3	8	0	3	3	4	2	7^b	0
21	3	1	3^d	3	12^b	0	4	4	4	3	6	0	3	3	3	2	9	0.5
22	3	2	3	3	10	0	4	4	4	3	8	0	3	2	3	2	12	2
23	..	..	3	3	9	0.5	4	3	4	3	8	0	3	2	3	2	13^b	2
24	..	..	..	..	5	0	4	3	4	3	8^g	0	4	4	3	2	14	0.5
25	3	4	4^c	2	5	..	3	3	3	3	7^b	0	3	3	4	2	15	0
26	4	4	3	2	$6^{b,h}$	2	4	3	4	3	7	0	3	3	3^d	1	11	0
27	3	3	3	2	8	1.5	3	3	3	3	7^a	0	3	4	3	2	14	1
28	4	2	4	3	8	0.5	4	4	3	3	$8^{a,b}$	0	3	3	3	2	13	1.5
29	4	2	4	3	9	1.5	3	4	3	3	9	0	3	2	4	2	11	0.5
30	4	2	4	3	9	1	3	3	3	3	11^b	0.5	3	2	4	2	10	0.5
31	4	3	4	3	8	0	4	3	3	3	10	1						
Mean	3.0	2.3	3.0	2.4	8.2	0.4	3.4	2.9	3.2	2.8	8.5	0.2	3.2	2.8	3.1	2.5	8.9	0.5

NOTE—For an explanation of these tables see this JOURNAL, 35, 47-49 (1930).

The character-figures of solar phenomena are estimated from the spectroheliograms which are made with a 2-inch solar image, usually in the early morning. Very bright chromospheric eruptions are reported in these notes if observed at any time during the day.

a, *b* Formation of a new group which later developed to average size or larger; (*a*) less than 30° from the center of the disk, (*b*) more than 30° from the center of the disk.
c, *d* Very bright chromospheric eruptions. (*c*) less than 30° from the center of the disk, (*d*) more than 30° from the center of the disk.
e, *f*, *g*, *h*, *i*, *j*, *k*, *l* Passage of a large or active group across the central meridian within 5°, 10°, 15°, 20°, 25°, 30°, 35°, 40° of the center of the disk, respectively.

PRINCIPAL MAGNETIC STORMS

SITKA MAGNETIC OBSERVATORY

JULY TO SEPTEMBER, 1946

(*Latitude 57° 03′.0 N., longitude 135° 20′.1 or 9^h 01^m.3 W. of Gr.*)

July 14—A brief minor disturbance beginning rather suddenly at 13^h30^m GMT, was characterized by a change of 520 gammas in H. The displacement of all three elements continued for about an hour, and a K-index of 7 was recorded for this period.

July 26-27—A major magnetic storm began sharply at 18^h 47^m GMT, July 26, and continued for fourteen hours, after which it died down almost as suddenly as it had started. The greatest disturbance, consisting chiefly of short-period oscillations of large amplitude, occurred between the first and the ninth hour GMT when three K-indices of 9 were recorded. During the half-hour period between 01^h 15^m and 01^h 45^m, July 27, H increased 1310 gammas, and during the period between 07^h 30^m and 08^h all three of the elements decreased suddenly with H changing 1645 gammas, Z, 980 gammas, and D, 3° 06′.

August 14—A brief disturbance beginning gradually at 07^h GMT, August 14, attained greatest activity during the twelfth hour when a K-index of 8 was recorded. The disturbance died out rather suddenly at 13^h on the same day.

August 17—A brief disturbance beginning sharply at 08^h 05^m GMT, August 17, continued for about an hour and a K-index of 7 was recorded.

August 31—A brief magnetic disturbance beginning gradually at 04^h GMT, August 31, was characterized chiefly by a large bay in Z and H of approximately three hours' duration. Beginning at 05^h 35^m, D suddenly decreased 2° 47′ but had returned to its normal recording position by 06^h. A K-index of 8 was recorded.

September 4—A brief minor disturbance began rather sharply at 09^h 45^m GMT, September 4, and lasted for about two hours. A K-index of 7 was recorded when D changed 114′ during the eleventh hour.

September 18-19—A major magnetic storm began rather suddenly at 00^h GMT, September 18. The activity for the first seventeen hours of the storm consisted chiefly of short-period, large-amplitude oscillations with an occasional sudden increase or decrease of one of the elements. During the eighth hour H decreased about 1200 gammas and D about 140′. During the thirteenth hour D made rapid changes of almost 4°. K-indices of 7, 7, 9, 8, 9, and 8 were recorded for this period of the storm. Following the seventeenth hour moderate activity continued until 12^h, September 19, when a short

period of violent activity occurred, and a K-index of 8 was recorded. The storm died out suddenly during the sixteenth hour.

September 22-23—A major magnetic storm began suddenly during the fifth hour on September 22. The entire storm was characterized by short-period oscillations, mostly of large amplitude. During the first fourteen hours K-indices of 8, 8, 9, 9, and 9 were recorded. For the next eight hours the oscillations were of smaller amplitude with K-indices of 5 being recorded. The storminess increased during the second hour on September 23 and the amplitude of the oscillations again increased. During the second part of the storm, however, the periods were of longer duration. After the eighteenth hour on September 23 the storm gradually died out. The K-indices for the second part of the storm were 7, 8, 9, 7, 8, and 9. During the eleventh hour on September 22 D changed about 5° and H about 2430 gammas.

September 27-29—A moderate magnetic storm began gradually at about 06^h GMT, September 27. After twenty-four hours of mild disturbance the activity began to increase and at 09^h, September 28, changed to short-period oscillations of large amplitude. After 18^h, September 28, the storm gradually died out, but moderately disturbed conditions followed for several days. K-indices of 8, 7, 8, and 8 were recorded during the severe part of the storm.

Merril L. Cleven, *Observer-in-Charge*

Cheltenham Magnetic Observatory

July to September, 1946

(*Latitude 38° 44′.0 N., longitude 76° 50′.5 or 5^h 07^m.4 W. of Gr.*)

July 18-19—Following a very slight disturbance in D and H, a mild magnetic storm began with a sudden commencement in all three elements at 09^h 04^m GMT, July 18, and persisted until about 15^h, July 19. The first half of the storm consisted of rapid pulsations of small amplitude in both H and D. The character of the disturbance gradually changed to irregular oscillations of moderate amplitude, the change occurring in D at about 22^h, July 18, and in H at about 02^h, July 19. The Z-trace did not exhibit serious disturbance at any time. Two K-indices of 5 and six of 4 were recorded.

July 26-27—A severe magnetic storm began with a sudden commencement in all three components at 18^h 46^m GMT, July 26. The storm was severe from the time of the sudden commencement until about 08^h, July 27, when the large rapid oscillations suddenly decreased in amplitude. The storm had subsided by 13^h, July 27, after which time only a slight disturbance continued. The disturbance characteristics were similar for all three traces, usually consisting of very rapid pulsations of varying amplitude. Between 02^h and 03^h, July 27, strong westerly motion of the needle took place and a

west extreme occurred at $03^h\ 01^m$. Very rapid easterly motion then set in and in fifteen minutes the needle had reached a position approximately at its east extreme. The *D*-range was scaled as 178′ for the 15-minute interval and 180′ for the storm-range. Similar though less intense *D*-movement occurred two hours later with the peak, representing west motion, occurring at $05^h\ 11^m$, July 27. The *H*-trace increased in a steady although irregular manner until $01^h\ 06^m$, July 27, when a maximum was reached. *H* then steadily decreased until $02^h\ 39^m$ at which time a very rapid decrease set in, culminating in a minimum *H*-value of 17,347 gammas at $02^h\ 53^m$. The *H*-range for this period was about 1500 gammas, which represented the *H*-range for the storm. A similar though less intense depression in *H* occurred two hours later at about $05^h\ 10^m$. *Z* increased steadily until $00^h\ 46^m$, July 27, when a sharp rise occurred, the maximum being reached shortly after 01^h. *Z* then decreased rapidly reaching a minimum between 02^h and 03^h. The *Z*-range for this period, which also represented the *Z*-range for the storm, was about 1130 gammas. A second important depression in *Z* occurred about two hours later. The *K*-indices for the five periods beginning at 18^h, July 26, and ending at 09^h, July 27, were 8, 7, 9, 9, and 8, respectively.

July 28-30—A moderate magnetic storm commenced at about 20^h GMT, July 28, and lasted until about 19^h, July 30. Throughout the storm the *H*-trace was characterized by rapid oscillations of small amplitude and of moderate amplitude; in *D* rapid oscillations of small amplitude predominated. One *K*-index of 6, four of 5, and eight of 4 were recorded. Minimum *H* was 18,028 gammas.

August 13-17—A prolonged period of general disturbance started with an abrupt beginning in *H* and *D* at $19^h\ 02^m$ GMT, August 13, and continued until about 23^h, August 17. Irregular oscillations of moderate amplitude and short-period oscillations took place. Four *K*-indices of 5 were recorded.

August 30-31—A short-lived storm of moderate intensity began with a sudden commencement in all three elements at $22^h\ 40^m$ GMT, August 30, being proceeded by about four hours of slight disturbance in *H*, and ended at about 10^h, August 31. Irregular oscillations of moderate amplitude occurred in all components. *K*-indices for the intervals from 21^h, August 30, to 09^h, August 31, were 5, 4, 6, and 6.

September 17-19—A storm of moderate severity began with an abrupt beginning in all three elements near 24^h GMT, September 17, and continued until about 16^h, September 19. The most disturbed part of the storm took place within the first thirteen hours of September 18. The storm was characterized by irregular oscillations of moderate amplitude upon which were superimposed short-period oscillations of small amplitude. Maximum east motion of the needle was recorded at $09^h\ 22^m$, September 18, at which time a steady, sharp westward movement began with maximum west declination being reached at $13^h\ 08^m$, September 18. The *D*-range for this

interval was 63′, which represented the D-range for the storm. Following an initial slight increase, H decreased in an erratic though gradual manner with the minimum of 17,938 gammas occurring at 07^h 33^m, September 18. The H-range was 320 gammas. Z exhibited a pronounced drop between about 06^h and 08^h 03^m, September 18, at which time the minimum was reached. Z then increased rapidly for three hours, fell slightly, and then displayed a steady and rather smooth increase until 19^h 24^m, September 18, when a maximum was reached. The Z-range was 490 gammas. Three K-indices of 7 and four of 6 were recorded.

September 21-24—A severe magnetic storm began with a sudden commencement in all three elements at 17^h 13^m GMT, September 21, and lasted until about 14^h, September 24. The storm could clearly be divided into three parts. The first part consisted of a relatively minor disturbance with some irregular and short-period motion from the time of the sudden commencement until 10^h 12^m, September 22. At this time the second phase of the storm began with a second sudden commencement. All three elements exhibited an extraordinary example of very rapid pulsations of large amplitude for approximately eight hours. From about 17^h, September 22, the amplitude of the oscillations began to decrease gradually, although their rapid character persisted, until about 02^h, September 23, when the third phase of the storm set in. This phase consisted of irregular oscillations of moderately large amplitude. An interesting and well-defined peak occurred in D at 11^h 33^m, September 22, representing maximum westward motion at this time. The range in D for this peak was 189′; this represented most of the D-range for the storm which was 206′. Minimum H appeared to occur at the same time as this peak in D, that is, at 11^h 33^m, September 22, at about 17,380 gammas. The H-range for the storm was somewhat uncertain but was scaled at approximately 1150 gammas. Low values of Z occurred between 06^h and 07^h, and near 12^h, September 21, and at about 06^h 27^m, September 23, when a minimum was reached. The Z-maximum was somewhat doubtful and led to a range of about 530 gammas. K-indices for September 22 were 4, 7, 7, 9, 9, 9, 6, and 5 (sum 56), and for September 23, 6, 7, 8, 4, 6, 6, 5, and 6 (sum 48).

September 27-29—A moderate magnetic storm began gradually at about 06^h GMT, September 27, and lasted until about 06^h, September 29. The disturbance consisted predominantly of irregular oscillations of moderate amplitude in all three traces. Minimum H of 18,017 gammas occurred at 15^h 39^m, September 28. The K-sum for September 28 was 40; two K-indices of 6 and six of 5 were recorded.

William E. Wiles, *Observer-in-Charge*

Tucson Magnetic Observatory

July to September, 1946

(Latitude 32° 14′.8 N., longitude 110° 50′.1 or 7^h $23^m.3$ W. of Gr.)

July 7-8—A moderate storm of only about twenty-four hours' duration began at 03^h GMT, July 7. Most of the activity occurred during the first half of the period and was characterized by moderate, fairly long-period changes in *H*. Little activity was noted in *D* and *Z*. Range in *H*: 163 gammas.

July 18-19—At 09^h 04^m GMT, July 18, a sharp increase of 35 gammas in *H* marked the beginning of a storm in which the ranges were small. There was, however, a considerable amount of moderately short-period activity in *H* and *D* for about seventeen hours, after which the periods of oscillation became longer. Activity ceased quite suddenly about 14^h, July 19. Ranges: *D*, 20′; *H*, 98 gammas.

July 25-30—On July 25, about 15^h GMT, moderate storm-conditions appeared without marked characteristics other than general roughness. This continued until 18^h 47^m, July 26, when a very violent phase of the storm commenced. A sudden increase of 66 gammas in *H* was immediately followed by a sharp decrease of some 300 gammas. Within the next hour *H* covered a range of more than 450 gammas. During the nine hours following the sudden commencement there were large swings in *D* and *H*, superimposed on which was an almost continuous very short-period activity. The short-period oscillations died out about 04^h, July 27, but the longer period oscillations continued until about 12^h, July 27. The following twenty-four hours were fairly quiet, but with a markedly depressed *H*. Some activity began again about 14^h, July 28, with moderate ranges and both long- and short-period oscillations continuing until about the end of the Greenwich day July 30. Ranges: *D*, 50′; *H*, 495 gammas; *Z*, 100 gammas.

August 13-17—A sudden commencement at 19^h 01^m GMT, August 13 (a 25-gamma increase in *H*), marked the beginning of a long but moderate storm. There were no outstanding characteristics other than a generally disturbed condition which lasted until about 16^h, August 17.

August 30-31—A moderate storm began suddenly at 22^h 40^m GMT, August 30, and lasted only about seventeen hours. A peak in eastward *D* shortly after 05^h, August 31, and a few swings in *H* were the chief characteristics. Ranges: *D*, 22′; *H*, 172 gammas.

September 16-17—A moderate storm of only sixteen hours' duration began with a small but sharp disturbance in *H* at 13^h 47^m GMT, September 16. Range in *D* was small and in *H*, slightly greater. There were no outstanding characteristics. Range in *H*: 150 gammas.

September 17-19—At 23^h 51^m GMT, September 17, a sudden increase of 25 gammas in *H* occurred, marking the commencement of a moderately

severe magnetic storm which lasted just forty-eight hours. Fairly large variations of long period were recorded in D and H during the first twenty-four hours; even slower-speed changes occurred during the second half of the storm. A gradually diminishing activity came to an end about 24^h, September 19. Ranges: D, 23′; H, 200 gammas.

September 21-24—A sharp disturbance of all three elements was recorded at 17^h 13^m GMT, September 21, consisting of an increase of 26 gammas in H, followed immediately by a sharp decrease of the same amount, a sudden decrease of 4′ in eastward D, followed immediately by a sudden increase of 9′, a sudden increase of about 2 gammas in Z, followed immediately by a decrease of about 3.5 gammas. It is very unusual at this Observatory for D to show a relatively greater effect than H at the time of a sudden commencement; and it is also unusual for Z to show a sharp record of a sudden commencement. Following the initial disturbance, activity was light until about 04^h, September 22, at which time moderately large swings in D and H began. At 10^h 11^m, September 22, H increased suddenly by 141 gammas to mark the beginning of a period of extremely violent short-period fluctuations in all elements. Between 11^h and 12^h, and again between 13^h and 17^h, the oscillations were of extremely short period and large amplitude, so that in some places little more than turning points could be seen on the magnetogram, although the mean values of the elements during these periods seemed to be near normal. The violence of the activity decreased at 17^h, September 22, but the very short-period oscillations continued until about 02^h, September 23. Then there followed several hours of large swings in D and H of periods of oscillation approximating one hour. From about noon on the Greenwich day September 23, activity became more irregular and of diminishing intensity until the end of the storm about the middle of September 24. Ranges: D, 51′; H, 390 gammas; Z, 71 gammas.

September 27-30—A moderately severe storm began without sudden commencement during the first half of the Greenwich day September 27. Greatest activity occurred during the Greenwich day September 28, followed by a gradual diminishing of the disturbance until the end of the storm toward the end of September 30. Ranges: D, 22′; H, 187 gammas.

C. Edward Westerman, *Observer-in-Charge*

Alibag Magnetic Observatory

July to September, 1946

(*Latitude 18° 38′.3 N., longitude 72° 52′.3 or 4^h $51^m.5$ E. of Gr.*)

July 26-27—A strong magnetic storm commenced suddenly at 18^h 45^m GMT, July 26, with a 147-gamma rise in H, 29-gamma fall in Z, and in-

crease in westerly declination by 3′.1, all in about a minute of time, followed by rapid fluctuations in all the elements. H attained its maximum at 18^h 58^m, and thereafter began to fall with frequent rise and fall which resulted in a number of peaks. All the three elements recorded rapid oscillations throughout the storm which ended at about 12^h 30^m, July 27. Two K-indices of 8 were attained for the intervals between 18^h to 21^h, July 26, and 00^h to 03^h, July 27, and also two of 7 and one of 6 during the storm. Ranges: H, 499 gammas; Z, 103 gammas; D, 12′.5.

September 17-19—A sudden increase of 34 gammas in H and fall of 20 gammas in Z at 23^h 48^m GMT, September 17, marked the beginning of a moderate storm which died away at about 17^h, September 19. All the three elements recorded minor fluctuations throughout. During the storm one K-index of 7 and one of 6 were attained. Ranges: H, 283 gammas; Z, 68 gammas; D, 6′.9.

September 21-23—A "sudden-commencement" storm began at 17^h 11^m GMT, September 21, raising H by 51 gammas and lowering Z by 12 gammas in less than three minutes of time. After a period of slight activity which lasted for about twelve hours, H began to fall rapidly at 04^h 25^m, September 22, and in about two hours decreased by 229 gammas. Thereafter H became fairly steady with minor oscillations until about 10^h 10^m when an admixture of large and small oscillations was recorded in all the three elements until about 19^h 10^m, September 22, which interval can be considered to be the intense phase of the storm. The storm ended at about midnight on September 23. Two K-indices of 9 were reached during the successive intervals between 12^h and 18^h, September 22. Two other three-hour intervals recorded K-indices of 7 and five others of 6. Ranges: H, 425 gammas; Z, 146 gammas; D, 8′.2.

September 27-29—A moderate disturbance with a very indefinite beginning near 06^h GMT, September 27, continued until about 01^h 30^m, September 29, with some large occasional rise and fall in the elements. Only two K-indices of 6 and three of 5 were recorded during the disturbance. Ranges: H, 222 gammas; Z, 57 gammas; D, 5′.3.

M. P. Rao, *Assistant*

Huancayo Magnetic Observatory

April to September, 1946

(Latitude 12° 02′.7 S., longitude 76° 20′.4 or 5^h $01^m.4$ W. of Gr.)

April 22-24—A long but moderate magnetic storm began on April 22 at 06^h 58^m GMT with a sharp increase in H of 43 gammas in four minutes, and was followed for about 26 hours by minor disturbances characterized by small, rapid peaks and bays. A general increase in H began at 09^h 20^m,

April 23, with somewhat larger but still rapid peaks and bays, coming up to a low maximum at the usual midday period and then followed by a long, jagged decline lasting all afternoon and ending with a minimum of 298 gammas below the base-line at 23^h 42^m. After this the storm gradually died out with moderate, slow peaks and bays during a slow increase in *H* for another twelve hours on April 24. *D* and *Z* showed only mild activity during only the daylight hours of April 22 and 23.

July 26—A short but very strong magnetic storm began at 19^h 47^m GMT, July 26, with a sudden commencement showing an increase of over 200 gammas in three minutes. This was followed by almost six hours of sharp, rapid movements with only a couple of small peaks and bays, but with a continual decrease in *H* until 00^h 30^m, July 27, when the *H*-trace dropped rather smoothly over 280 gammas in forty minutes. This was followed by seven hours of larger, less oscillatory peaks and bays to end the storm at approximately 08^h, July 27, with *H* recording from the reserve mirror well below the base-line. *D* and *Z* both showed the sudden commencement, and were sharply disturbed inside a small range during the height of the storm. *H* registered low values for a couple of days afterward.

September 18-20—A little more than a day after a mild magnetic disturbance on September 16, a strong magnetic disturbance began on September 17 with a sharp, rapid increase in *H* of 66 gammas at 23^h 50^m GMT. This was followed by a remarkably long, almost smooth decrease in *H* to 206 gammas below the base-line at 03^h 18^m, September 18. After this there were two long, slow peaks and bays of moderate size, and at 11^h 50^m began a four-hour period of sharp, rapid peaks and bays, followed by another eight hours of small but relatively rapid movements during the night. Then there were slow, moderate movements during the night hours and two sharp peaks and bays on September 20 during the forenoon daylight hours. *H* recorded relatively low values during the progress of the storm, and came back rather slowly during the last day. *D* and *Z* were only mildly disturbed during the daylight hours of the storm period.

September 21-23—A very violent magnetic storm began on September 21 at 17^h 13^m GMT, with a 27-gamma decrease and an immediate 237-gamma increase in *H* in less than four minutes. The following seventeen hours were characterized only by a number of small, rapid movements and a low bay at 06^h 27^m, September 22, 173 gammas below the base-line. At 10^h 12^m the violent stage of the storm began with a 140-gamma increase in *H* in one minute, and this was followed by movements so rapid and so large for the next seven and a half hours that it was possible to follow the changes on the trace of the insensitive variometer only (scale-value = 23.5 gammas per mm). The range in *H* was 848 gammas between the maximum at 13^h 30^m and the minimum at 14^h 32^m, but there were several rapid changes of over 700 gammas in a few minutes during the peak of the storm. The narrow

peaks and bays were so sharp and frequent that no detailed description is possible. The most intense activity began to die down by 17^h, September 22, although following there were about nine hours of smaller, but still very rapid movements. The storm ended gradually and, although there were a few large peaks and bays during the midday hours of September 23, recording was almost completely normal on September 24. *D* and *Z* were very sharply disturbed and recorded rapid, small peaks and bays during the most active phase of the storm, but showed no other peculiarities or unusual changes.

September 27-29—A mild magnetic disturbance began gradually on September 27 at about 13^h GMT and was chiefly characterized by numbers of moderate peaks and bays in *H* during the midday hours of September 27 and 28, and by a slow, deep minimum in *H* at $00^h\ 37^m$, September 29, 150 gammas below the base-line, and actually after the disturbance had seemingly ended. Neither *D* nor *Z* were unusually affected.

PAUL G. LEDIG, *Observer-in-Charge*

WATHEROO MAGNETIC OBSERVATORY

MAY TO SEPTEMBER, 1946

(Latitude 30° 19′.1 S., longitude 115° 52′.6 or $7^h\ 43^m.5$ E. of Gr.)

The following four additional storms were recorded during May and June, 1946; descriptions were received after publication of the June issue of the JOURNAL.

May 5-11—A moderate disturbance with small, rapid fluctuations commenced at $21^h\ 47^m$ GMT, May 5. From $04^h\ 15^m$ to $04^h\ 31^m$, May 6, a peak occurred in *H* and a minimum was reached at $07^h\ 04^m$, giving a range of 95 gammas. At $22^h\ 27^m$, May 6, a fairly sudden increase occurred of 30 gammas in *H* with a corresponding drop in other elements, followed by a further upward change in *H*. The range in *H* from $01^h\ 19^m$ to $06^h\ 56^m$ was 147 gammas. Moderately disturbed conditions with small, rapid fluctuations in all three elements continued until about 14^h, May 7. Small, rapid fluctuations recommenced at $22^h\ 20^m$ on the same day with a sharp peak at $13^h\ 02^m$, May 8, giving a range of 86 gammas in *H* between $06^h\ 13^m$ and $13^h\ 02^m$. Thereafter, fluctuations were slower, May 9 being moderately disturbed with variations of the order of an hour in period. Conditions were almost normal again by 08^h, May 10. There was a fairly sharp rise of 15 gammas in *H* at $22^h\ 41^m$, May 10, followed by quiet conditions until $03^h\ 21^m$, May 11, when rapid fluctuations commenced particularly in *H*. A downward swing in *H* between $08^h\ 25^m$ and $09^h\ 08^m$ culminated in a deep bay reaching a minimum at $08^h\ 40^m$, followed by fairly slow fluctuations. There was a range

of 142 gammas from 08^h 40^m to 16^h 52^m. Conditions were quiet by 18^h, May 11. Ranges: *H*, 192 gammas; *Z*, 151 gammas; *D*, 23′.

May 20-24—A moderate disturbance commenced at 20^h 58^m GMT, May 20, with a rapid drop of 25 gammas in *H* and corresponding increases in the other elements. There were small and fairly rapid fluctuations at first superimposed upon and followed by slow variations in all elements throughout May 21. From 03^h 00^m, May 22, *H* dropped through 103 gammas in 85 minutes. The subsequent disturbance consisted mainly of large, slow fluctuations in all elements, together with some superimposed small, rapid variations. There were rather marked peaks in all elements at 12^h 30^m, May 23, and at 15^h 05^m, May 24. Conditions were normal by 20^h, May 24. Ranges: *D*, 16′; *H*, 153 gammas; *Z*, 103 gammas.

June 5-6—There was a small, fairly sudden commencement at 20^h 10^m GMT, June 5, with an increase of 17 gammas in *H*. Only a minor disturbance followed, however, and all elements were quiet again by 16^h, June 6. Ranges: *D*, 7′; *H*, 65 gammas; *Z*, 57 gammas.

June 7-9—A "sudden commencement" at 07^h 39^m GMT, June 7, with an increase of 11 gammas in *H*, was followed by small rapid fluctuations for the next four hours particularly in *H*. Then there were large, slow fluctuations with a slight depression in *H* throughout the next two days until 17^h, June 9, when all elements had once more returned to normal. Ranges: *D*, 13′; *H*, 99 gammas; *Z*, 77 gammas.

June 27-29—A moderate disturbance commenced with a fairly abrupt change of +12 gammas in *H* at 17^h 30^m on June 27. The change in the other elements was not so marked and conditions remained fairly normal apart from small, rapid fluctuations, until larger and slower variations in all elements occurred between 12^h and 22^h, June 29. *H* gradually increased and *Z* decreased during this period. Quiet conditions prevailed again from 22^h onwards on June 29. Ranges: *D*, 15′; *H*, 93 gammas; *Z*, 107 gammas.

July 18-19—A mild storm was recorded with a "sudden commencement" at 09^h 04^m GMT, July 18, *H* increasing by 13 gammas. At the same time *D* decreased by 2′, then increased by 3′, while *Z* decreased by 13 gammas and almost immediately resumed its former value. Moderately disturbed conditions prevailed until about 14^h 20^m, July 19, when the storm ended. During this period there were fairly large, slow fluctuations on which small, rapid variations were imposed from about 22^h, July 18, to 08^h, July 19. At 14^h 15^m, July 18, *H* increased by 21 gammas in one minute, reaching its maximum for the storm at 14^h 16^m. The minimum occurred at 06^h 44^m on the following day. The storm culminated in a large peak in *H* with corresponding decreases in the other elements at 13^h 40^m, July 19. Ranges: *D*, 13′; *H*, 93 gammas; *Z*, 78 gammas.

July 26-27—On July 26 a fairly severe storm occurred with a sudden commencement at 18^h 47^m GMT. At the commencement *H* and *Z* changed

too rapidly for the spots to record. The initial increase in H amounted to 115 gammas, then after a few rapid fluctuations of the order of 20 gammas, H increased still further, reaching its maximum for the storm at $19^h\ 01^m$. A feature of the disturbance was the almost regular periodicity of the large swings which occurred simultaneously in all elements. Peaks occurred in H at $19^h\ 01^m$, $21^h\ 04^m$, $21^h\ 56^m$, $23^h\ 05^m$, and $24^h\ 00^m$, July 26, and at $01^h\ 20^m$, $02^h\ 16^m$, $03^h\ 00^m$, and $03^h\ 54^m$, July 27. Superimposed on these large swings were very rapid fluctuations of the order of 30 gammas. From 19^h, July 26, H showed a downward tendency until its minimum was reached at $07^h\ 10^m$, July 27, after which it began to rise fairly rapidly but with slower and smaller variations. All the elements became much less agitated from 05^h onward, July 27, and by 20^h comparatively quiet conditions once more prevailed. The storm can be considered to have ended by 21^h, July 27. The Z-spot moved off the edge of the record several times on July 27. Ranges: D, 54′.5; H, 470 gammas; Z, > 205 gammas.

There were no major magnetic disturbances during August, but two moderate disturbances were recorded.

August 13-14—This disturbance commenced at $19^h\ 03^m$ GMT, August 13, with a fairly slow increase in H of about 10 gammas. D and Z showed only a slight decrease with some small fluctuations. Small, rapid variations, particularly in H, were noticeable from $05^h\ 20^m$ to $08^h\ 50^m$, August 14. H reached its maximum at $01^h\ 04^m$, August 14, then fell during the following eleven hours to a minimum at $11^h\ 45^m$, followed by a fairly rapid increase during the next fifty minutes. Comparatively normal conditions prevailed again by 14^h, August 14. Only moderate changes were observed in D and Z. Ranges: D, 12′; H, 128 gammas; Z, 114 gammas.

August 30-31—There was a moderate "sudden commencement" at $22^h\ 50^m$ GMT, August 30, when H increased by about 15 gammas in a minute, with sudden but smaller changes in D and Z. H increased slightly during the next hour to a maximum at $23^h\ 25^m$, then decreased rapidly to a minimum at $05^h\ 33^m$, August 31. The variations in all elements were mainly rapid and of small amplitude. D and Z were rather quiet throughout compared with H. Conditions were quite normal again by $18^h\ 30^m$, August 31. Ranges: D, 19′; H, 146 gammas; Z, 107 gammas.

September 16-17—A moderate disturbance commenced between 13^h and 14^h GMT, September 16. The beginning was probably fairly sudden but it was not recorded at Watheroo because scale-value observations were in progress at the time. There were some large, slow-period movements in all three elements between 16^h and 21^h, September 16, followed by short-period variations until the disturbance ended at $11^h\ 07^m$, September 17. None of the elements departed very greatly from the normal value, although H remained slightly depressed for a further ten hours after the storm ended. Ranges: D, 16′; H, 88 gammas; Z, 93 gammas.

September 17-19—A storm of average severity but of greater duration than usual, began at $23^h\ 50^m$ GMT, September 17, with a sudden, small increase of 5 gammas in H and corresponding decreases in D and Z. Within a minute the swing in all three elements was reversed and for the next thirteen hours rapid fluctuations of the order of 15 to 30 gammas were recorded, while H dropped from a very high value at $00^h\ 15^m$, September 17, to its minimum at $12^h\ 50^m$, the same day. For the next six and a half hours, up to $19^h\ 30^m$, large, slow swings were recorded on all three elements and these were followed by small, rapid fluctuations which continued with decreasing amplitude through to 08^h, September 19. Then followed five hours of relative calm, until at $12^h\ 56^m$ a large swing occurred in all three elements, the value of H increasing by 135 gammas in thirteen minutes and attaining its maximum for the storm. After this fluctuation the elements were slightly disturbed for a further eight hours, during which time conditions became gradually quieter and the value of H rose steadily toward the normal. The storm may be considered to have ended by $21^h\ 20^m$, September 19, although a slight unsteadiness was noticeable during the ensuing ten hours. Ranges: D, 40′; H, 231 gammas; Z, > 190 gammas.

September 21-24—A very severe storm began with a marked "sudden commencement" at $17^h\ 14^m$ GMT, September 21. The value of H increased 44 gammas in a minute, D decreased by 4′, and Z dropped 24 gammas in the same time. For the following eleven hours the elements showed only small, rapid fluctuations about values that were practically normal. This first phase of the storm was followed by the onset of the main disturbance. H decreased with unusual rapidity, dropping by 130 gammas in thirty-eight minutes from $04^h\ 35^m$ to $05^h\ 13^m$, September 22. For the next five hours moderately large, rapid variations were noticeable in all elements. At $10^h\ 12^m$, September 22, a period of rather violent fluctuations commenced and this continued until $19^h\ 10^m$. During this period the spots moved so rapidly and crossed each other so frequently that it is difficult to decipher the record completely. The Z-spot was off the edge of the recording paper at intervals. The Aurora Australis was visible at the Observatory (latitude 30° south) from $11^h\ 40^m$ to $12^h\ 05^m$, as a red glow, with an altitude of about 30° and its center moving across from 10° east to 15° west of south. There were greenish-blue bands clearly visible, radiating upward from the center of the glow, and these became gradually fainter. Following the major phase of the storm, all elements showed small, rapid variations from $19^h\ 10^m$, September 22, until 04^h, September 23. These rapid variations were then followed by longer-period swings of moderate to large amplitude of the order of 25 to 75 gammas, which continued until $00^h\ 15^m$, September 24. Only small pulsations remained to disturb the record thereafter, although the value of H was depressed until about 11^h, September 24. All traces of the storm had disappeared by $18^h\ 52^m$, September 24. Ranges: D, 71′; H, 397 gammas; Z, > 250 gammas.

September 27-30—A moderate disturbance began at 09^h 18^m GMT, September 27, with a slow but marked increase in all elements. Slow variations of moderate amplitude were recorded on D, H, and Z during the following fourteen hours. The next period from 23^h 10^m, September 27, to 12^h 10^m, September 28, was characterized by small, rapid variations. These in turn were followed by further large, slow swings on all three elements as the value of H gradually fell to its minimum at midnight, September 28. Conditions were rather quiet during the ensuing thirteen hours up to 12^h 40^m; meanwhile the value of H steadily rose toward its normal level. However, conditions remained somewhat disturbed during a further day and a half, and it was 20^h, September 30, before all traces of the disturbance had disappeared. Ranges: D, 27′; H, 149 gammas; Z, > 205 gammas.

F. W. Wood, *Observer-in-Charge*

Hermanus Magnetic Observatory

July to September, 1946

(*Latitude 34° 25′.2 S., longitude 19° 13′.5 or 1^h 16^m.9 E. of Gr.*)

July 3—A minor disturbance began with a small "sudden commencement" at 01^h 21^m GMT, July 3, and continued until about 17^h.

July 6-9—Small "crochets" on all three traces at 02^h 07^m GMT, July 6, were followed by a storm of moderate intensity which began at about 03^h 25^m, July 7, and persisted until about 11^h, July 9. The highest K-index was 5.

July 14-15—The minor disturbances on these days terminated with bays of K-index 5 on all three traces during the second three-hour period, July 15.

July 16-19—Minor disturbances on July 16-17 were followed at 09^h 03^m GMT, July 18, by a sudden-commencement storm of moderate intensity. The disturbance, which continued until about 14^h, July 19, was characterized by large bays of irregular shape, with small, rapid oscillations superimposed on the larger movements during the first nine hours of the storm. H and Z each had a range of 120 gammas.

July 22-23—The traces were slightly disturbed during these days.

July 26-27—A storm of considerable severity began abruptly at 18^h 46^m.5 GMT, July 26, H increasing by 122 gammas in fourteen minutes. A series of large irregular fluctuations followed, which continued until H and D had reached their lowest points between 06^h and 07^h, July 27. All three elements recovered rapidly after that, the effect in the case of D being a spectacular sweep of 45′ in one and one-half hours. The ranges of the storm were: H, 340 gammas; Z, 206 gammas; D, 52′ ≡ 211 gammas. K-indices of 7 were assigned to each of the five three-hour periods between 18^h, July 26, and 09^h, July 27.

July 28-30—The main features of the moderate disturbances recorded during this period were (*a*) small irregular oscillations ($K \leq 3$) between $04^h\ 30^m$ and $13^h\ 30^m$ GMT, July 29, and between 01^h and 14^h, July 30, and (*b*) large irregular bays ($K \leq 5$) during the last three-hour period on July 28, and during the first and sixth three-hour periods on July 29.

August 6-7—Small, crochet-shaped deflections ($K = 2$) at $10^h\ 01^m$ and at $13^h\ 10^m$ GMT, August 6, were followed on August 7 by minor disturbances which continued throughout the day.

August 11-17—The minor disturbances during this period began with large, shallow bays on all three traces between $04^h\ 30^m$ and 07^h GMT, August 11, and ended with rather sharper bays between $21^h\ 30^m$ and $22^h\ 30^m$, August 17. The longest active spells were from $04^h\ 30^m$, August 11, to 07^h, August 12, and from 03^h, August 14, to 06^h, August 15. Sharp changes occurred in all three elements at $13^h\ 00^m$, August 11 (H and Z, 28 gammas; D, 12 gammas in eight minutes) and at $19^h\ 01^m$, August 13 (H, 12 gammas). Between $20^h\ 20^m$ and $21^h\ 40^m$, August 14, D and Z described a complete oscillation of about 70-gamma range, the effect in the case of H being less marked.

August 23-24—Small jerks in all three elements at $09^h\ 33^m$ GMT, August 23, were followed by minor disturbances between 06^h and 09^h, August 24.

August 30-31—A brief storm of moderate intensity began with abrupt changes in all three elements at $22^h\ 40^m$ GMT, August 30 (H increased by 29 gammas in five minutes), and continued for about twenty-four hours. The ranges were H, 139 gammas; Z, 82 gammas; D, 18′.

September 7-12—There was minor activity throughout this period, the principal feature being a large bay (H, 32 gammas, Z, 41 gammas) between $22^h\ 20^m$ and 24^h GMT, September 10.

September 16-19—Two separate disturbances were recorded during this period. The first, a brief storm of moderate intensity, began with a sudden commencement at $13^h\ 46^m$ GMT, September 16 (H increased by 14 gammas in one minute). Z reached its maximum value and H its minimum at $19^h\ 03^m$, September 16. The ranges of the storm were: H, 145 gammas; Z, 160 gammas; D, 20′.5. While still recovering from the effects of this storm, all three traces exhibited fresh activity on September 17, when moderate bays (H, 37 gammas) developed between $19^h\ 45^m$ and $21^h\ 25^m$. A large, sudden commencement (H increased by 58 gammas in five minutes) at $23^h\ 50^m$, September 17, marked the beginning of the second storm, which was of considerable severity, and continued until about 17^h, September 19. The ranges of the storm were: H, 231 gammas; Z, 148 gammas; D, 19′.4.

September 21-24—This storm, which was of exceptional severity, had four distinct phases. The first began with abrupt changes in all three elements at $17^h\ 13^m$ GMT, September 21, when a small gap occurred in the records owing to the extreme rapidity of the initial movements, as well as to an unfortunate drop in the mains voltage. Minor disturbances followed

until the second stage began with further abrupt movements of the order of 25 gammas, at 04^h 25^m, September 22. During the ensuing three hours, H changed by 110 gammas, Z by 134 gammas, D by 22′. Superposed on the large movements recorded during this period, were short bursts of small irregular oscillations. The third and most active stage began with sudden changes in all three elements at 10^h 11^m, September 22. An almost continuous series of extremely violent, large-amplitude oscillations followed until about 18^h, September 22. Parts of the Askania magnetogram were undecipherable during this period, but a good record was obtained with the la Cour slow-run variometer. The fourth stage was of moderate intensity, and consisted of a series of irregular oscillations of varying amplitude and period. Prominent among these was a sharp peak in the D-trace between 16^h 00^m and 17^h 00^m, September 23, the highest point being 23′ more westerly than the values before and after. Small rapid oscillations were recorded between 09^h and 14^h, September 24, after which the storm died away. The storm was remarkable more for the violence of the oscillations, especially during the third phase, than for the ranges, which were as follows: H, 322 gammas; Z, 272 gammas; D, 58′.

September 27-30—A disturbance which began at about 06^h GMT, September 27, gradually developed into a storm of considerable violence. The storm, which continued into October, was most active during a three-hour period beginning at 17^h, September 27, and during the 24-hour period beginning at 03^h, September 28. Prominent among the moderate to strong movements recorded on September 28, was a large oscillation which began at 20^h 48^m in H and D, seven minutes later in Z. H increased 110 gammas in seventeen minutes, then decreased 39 gammas in fifteen minutes; Z decreased numerically by 110 gammas in seventeen minutes, then increased 32 gammas in fifteen minutes; westerly declination increased 12′ in ten minutes, then decreased 22′ in thirteen minutes. Since H had reached its minimum, and Z its maximum value, at 17^h 30^m, September 28, these violent movements accelerated their recovery. The ranges of the storm were: H, 188 gammas; Z, 176 gammas; D, 36′.

A. M. van Wijk, *Officer-in-Charge*

LETTERS TO EDITOR

(See also pages 500 and 556)

GEOMAGNETIC DISTURBANCE OF SEPTEMBER 16-23, 1946[1]

A week of geomagnetic disturbances, culminating in a "great storm" during September 21-22, coincided with the epoch of the autumnal equinox

[1]This account is reprinted from *Nature* [158, 477-479, October 5, 1946]. In this connection see also Principal Magnetic Storms in this issue [pp. 563-577].—*Ed.*

as well as with the passage across the Sun's disk of a large group of spots during September 13-26. Spots of area 500-1000 millionths of the Sun's hemisphere are, however, now fairly frequent with the rise towards maximum of the 11-year solar cycle; but the recent group with a maximum area around 1000 millionths represented a renewal of activity in the region of the great July sunspot. This recent epoch of geomagnetic disturbance opened on September 16 at 13^h47^m UT, with a "sudden commencement" but the small storm which followed may be taken as having ended on the following day about 06^h. Fourteen hours later a long-continued disturbance began somewhat indefinitely, and lasted until September 20, 00^h. The maximum ranges at Abinger during this interval of nearly three days were considerable, namely, 250 gammas in horizontal force and 290 gammas in vertical force, the latter range almost raising the status of the disturbance to that of a great storm. Although no specific solar flares can as yet be related to these two periods of magnetic disturbance, it should be noted that at the time of the sudden commencement on September 16, the center of the spot-group was within the central part of the Sun's disk, which is effective in the known statistical relationships between the greater magnetic storms and individual large sunspots. However, storms of moderate intensity do in any event occur with markedly increased frequency at the epoch of the equinoxes even at solar minimum.

The "great storm" which next followed was, with a high degree of probability, directly associated with one or more solar flares within this sunspot-region that had shown intense activity two months earlier. The magnetic storm began on September 21 with a marked "sudden commencement" at $17^h\,13^m$ UT, but activity did not become conspicuous until $04^h\,25^m$, September 22. The most intense period was still later, between 10^h and 22^h. Between 14^h and 15^h the movements of the traces were so rapid that ranges of 200 gammas in H in one minute of time were frequent. The storm ended rather uncertainly about 08^h, September 23. The extreme ranges at Abinger (kindly communicated by the Astronomer Royal) were: $2°16'$ in declination; 925 gammas in horizontal force; and 450 gammas in vertical force.

A complete but short-lived radio fade-out beginning at $11^h\,05^m$, September 21, was reported to Greenwich by Cable and Wireless Ltd. and during this fade-out a solar flare (not of great magnitude) was partially observed at Greenwich. But the statistical average time-interval between the beginning of a great magnetic storm and its antecedent intense solar flare is 2½ hours. This interval from the "sudden commencement" at $17^h\,13^m$, September 21, would place the probable flare during the Greenwich night hours. Solar observations in H_α from America, Australia, and India are required to pursue further the connexion between this storm and a specific solar outburst within the sunspot-area.

NOTES

(See also page 516)

47. *Sodankylä Observatory and magnetic survey of Finland*—In his letter of October 21, 1946, just after returning from a trip to Sodankylä Observatory, Dr. J. Keränen gives the welcome information that the geomagnetic and meteorological programs are once more being followed. We are indebted to Dr. Keränen for the following photographs of the magnetic variation and absolute houses. Dr. Sucksdorff, Magnetician of the Meteorological Office of Finland made observations during 1946 at most of the repeat-stations in Finland.

SODANKYLÄ OBSERVATORY, 1946 [MAGNETIC VARIATION (AT LEFT) AND ABSOLUTE HOUSES]

48. *Publication of magnetic data for the American republics*—The report entitled "Magnetic observations in the American Republics, 1941-44," prepared by the United States Coast and Geodetic Survey, has just been received from the printer. It may be purchased from the United States Government Printing Office, Washington 25, D. C., for $1.25. This publication is based upon a report originally prepared by Joel B. Campbell and Fred Keller, Jr.

49. *Recent magnetic observations in the Arctic*—Magnetic observations were made at eight stations near the North Geomagnetic Pole by Joel B. Campbell, Geophysicist of the United States Coast and Geodetic Survey, in connection with the Nanook Expedition of the United States Navy. One station was at Thule, Greenland, and the others were on Devon Island and neighboring islands in Canada.

Colonel C. S. Irvine, Commander of the *Pascusan Dreamboat*, announced that observations made during his non-stop flight from Hawaii over the Arctic to Egypt indicated the North Magnetic Pole is now some 200 miles

north-northwest of the position determined by Amundsen's work in 1904. This confirms generally the results of the Royal Air Force Expedition on the *Aries* in May 1945; that expedition had indicated a shift of some 300 miles in the same direction. It is hoped the JOURNAL may have more definite advice later.

50. *Magnetic survey of Uruguay*—Excellent progress is being made in the magnetic survey of Uruguay under the auspices of the Geographic Military Service. Out of a network of 77 proposed stations which represent a spacing of 50 or 60 km, 62 had been occupied by November 12, 1946, and it is expected that the remaining 15 stations will be occupied by the end of the year. A series of repeat-stations for reoccupation at stated intervals in the future is under consideration.

51. *Joint Meeting of the National Academy of Sciences and American Philosophical Society, October 17 to 23, 1946*—This meeting was largely devoted to matters bearing on rehabilitation of international scientific cooperation. There were in attendance, upon joint invitation of the Academy and the Society, some 30 delegates representing the Academies or corresponding scientific societies of 21 countries in a total of 30 countries invited. The sessions were largely devoted to presentation of statements from invited speakers followed by extensive discussions of the foreign delegates and others. The subjects were Astronomy, Meteorology, Oceanography, Geophysics, High-Speed Computing Machines, Mineral Resources, Epidemic Diseases, Nutrition, Plant Diseases, Problems of International Cooperation in Science concerned with (1) Publications and Exchange of Publications, (2) International Scientific Unions, (3) International Congresses of Science, (4) Interchange of Men of Science, and (5) United Nations Educational, Scientific, and Cultural Organization.

52. *Observations of Aurora Borealis during September 1946*—The following notes are from the *Hydrographic Bulletin* of September 28 and October 12, 1946, respectively.

The master of the steamship *Navarchos Koundouriotis* reports that on September 17, 1946, at $01^h\ 35^m$ UT, in latitude 41° 36′ north and longitude 66° 42′ west the northern horizon was illuminated by an arc extending 50° in length and 15° in altitude. The arc slowly "burst" into several bright illuminated beams resembling immense springs which remained visible for about ten minutes.

An officer of the M. V. *Coastal Archer* reports in latitude 32° 25′ north and longitude 78° 55′ west at $06^h\ 46^m$ UT, September 27, 1946, an unusual display of Aurora Borealis which covered an area of 50° of the horizon (from 350° to 040°) at an altitude of 5° to 15° above the horizon. At the onset the northern portion, from 020° to 040°, was deep red in color, with the middle and southern portions becoming so prior to the disappearance of the phenomenon at $07^h\ 08^m$.

53. *Personalia*—Dr. *J. Tuzo Wilson*, formerly of the Canadian Geological Survey, appointed Professor of Geophysics at the University of Toronto, Toronto, Canada, took up his duties there in September 1946.

Andrew Thomson was appointed as Controller of the Canadian Meteorological Service December 1, 1946. He succeeds the eminent Dr. *John Patterson*, with whom he has been associated for many years as assistant in the Service.

A. G. McNish, formerly Magnetician and Physicist, Department of Terrestrial Magnetism, Carnegie Institution of Washington, has been appointed Chief of the Section for Basic Ionospheric Research in the Central Radio Propagation Laboratory of the National Bureau of Standards, Washington, D. C. His appointment was effective from August 15, 1946.

E. J. Chernosky, who returned to Washington, D. C., last February after a term of service as Observer at the Huancayo Magnetic Observatory, has accepted a position at the Naval Ordnance Laboratory.

W. C. Parkinson, for many years Observer-in-Charge of the Watheroo Magnetic Observatory, Western Australia, and his son, *W. D. Parkinson*, who has also been engaged at the Observatory, reported at the Department of Terrestrial Magnetism, December 2, 1946.

During the month of November, lectures dealing with aspects of cosmic-ray research were given at the Department of Terrestrial Magnetism, Carnegie Institution of Washington, by Professor *E. Amaldi*, University of Rome, and Dr. *Marcel Schein*, University of Chicago.

James H. Baden, Jr., Geophysicist of the United States Coast and Geodetic Survey, has recently been assigned to the Sitka Magnetic Observatory.

Mlle. *Juliette Roquet* of the Institut de Physique du Globe of Paris began, on September 23, 1946, research at the Department of Terrestrial Magnetism of the Carnegie Institution of Washington as a fellow of the Institute of International Education (sponsored by the American Association of University Women).

Thomas Murphy, a graduate of University College, Dublin, began a year of study at the Department of Terrestrial Magnetism of the Carnegie Institution of Washington on October 31, 1946, as a fellow from the National University of Ireland.

A recent letter from Professor *John G. Koenigsberger* (33 Wildtalstrasse, 17b, French Zone, Freiburg in Br., Germany) states that he is now reinstated in his full rights as Professor after having been dismissed by the Nazi government. His health and that of his wife has suffered greatly. He would appreciate receiving reprints and other help from his friends in America.

It is with regret that the JOURNAL has to record the death on September 10, 1946, of Sir *Carruthers Beattie*, aged 80 years. It will be recalled that he

did much valuable pioneer magnetic work in South Africa and did much to place geomagnetic research in its present active status there.

H. H. Clayton died October 27, 1946, aged 85 years. While his chief work concerned meteorology and methods of long-range forecasting he was interested in, and contributed to, investigations on the relations between solar activity and aurora and geomagnetism.

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